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JOURNAL
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OFFICIAL ORGAN AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

VOL. 25 OCTOBER, 1932 No. 5

Seventeenth Annual Meeting of the Pacific Slope Branch, American Association of Economic Entomologists

The 17th annual meeting of the Pacific Slope Branch was held at Washington State College, Pullman, Washington, June 16 and 17. The meeting was called to order at ten o'clock A. M., Thursday, June 16. Following a short business meeting, papers were presented during the morning and afternoon of Thursday and during the forenoon of Friday. The annual dinner was held on the evening of the 16th with an attendance of approximately 40 entomologists and their wives On the afternoon of Friday the 17th several of the visiting entomologists visited the Entomology Department of the University of Idaho, at Moscow. Preceding and following the meeting, several entomologists visited the wireworm experiment station at Walla Walla, Washington. The total attendance at the Pullman meeting was 40. The following members were present: Roy E. Campbell, Walter Carter, Joseph C. Chamberlin, Huber C. Donohoe, Charles F. Doucette, W. P. Flint, R. A. Fulton, R. W. Haegele, Edward W. Jones, M. C. Lane, A. O. Larson, Randall Latta, Russell S. Lehman, E. J. Newcomer, D. D. Penny, L. P. Rockwood, A. R. Rolfs, H. A. Scullen, W. E. Shull, A. L. Strand, Robert E. Wall, R. L. Webster, Charles E. Woodworth, C. W. Woodworth.

PART I. BUSINESS MEETING

The business meeting was called to order by President E. M. List at ten o'clock Thursday, June 16. The following committees were appointed:

Affiliation Committee—Roy E. Campbell and H. A. Scullen.

Nomination Committee—A. O. Larson, L. P. Rockwood and E. J. Newcomer.

Auditing Committee—W. E. Shull and Charles F. Doucette.

Resolutions Committee—Joseph C. Chamberlin and A. L. Strand.

At the close of the program of papers, June 17, the following business was transacted:

The Affiliation Committee reported that the 1933 meeting will probably be held at Salt Lake City, and the 1934 meeting at Oakland. It was reported that the general association was considering changing the meeting time from June to early September, beginning with the 1935 meeting. This seemed to meet with the approval of those present.

The Auditing Committee reported favorably on the following financial statement of the Treasurer:

TREASURER'S REPORT

Balance on hand June 20, 1931		$ 9.06
Interest		.52
Refund from parent society for 1931 meetings		20.50
(Received June 7, 1932)		
Cash paid out:		
Postage and envelopes	$ 5.75	
Labor (Addressing letters)	1.75	
Mimeographing notices	2.31	
Balance on hand	$20.27	
	$30.08	$30.08

REPORT OF THE RESOLUTIONS COMMITTEE

WHEREAS, The Pacific Slope Branch of the American Association of Economic Entomologists has enjoyed a most successful meeting at Pullman, Washington, June 15–17, 1932, and

WHEREAS, The officers and faculty of Washington State College have furnished us the most pleasant and enjoyable facilities for conducting these meetings,

BE IT RESOLVED, That we extend to them our most sincere thanks and appreciation.

WHEREAS, The Pacific Slope Branch of the American Association of the Economic Entomologists has lost one of its most esteemed and valuable members in the untimely death of Mr. Anthony Spuler and his wife, Marie Waters Spuler,

WHEREAS, His death constitutes an important loss to the science of economic entomology in general,

BE IT RESOLVED, That this association extend its heartfelt and sincere sympathy to the relatives of Mr. and Mrs. Anthony Spuler, as well as an expression of our feeling of a personal and professional loss to the Washington State College and the Washington Agricultural Experiment Station.

JOSEPH C. CHAMBERLIN
A. L. STRAND

The Nominating Committee submitted the following nominations:

President ..... R. L. Webster
Vice-President ..... Geo. I. Reeves
Secretary-Treasurer ..... H. A. Scullen

The Committee's report was accepted and the officers duly elected. It was moved and seconded that the Secretary be authorized to insert order and family names following scientific names in titles of papers, or to refer the titles back to the authors for correction.

President W. P. Flint, of the Parent Association, gave a brief talk bringing greetings from the Parent Association.

The meeting adjourned at 12:45 P. M., June 17.

H. A. SCULLEN, *Secretary.*

PART II. PAPERS

EXPERIMENTS TO DETERMINE THE ATTRACTIVENESS OF VARIOUS AROMATIC COMPOUNDS TO ADULTS OF THE WIREWORMS

Limonius (Pheletes) canus Lec. and *Limonius (Pheletes) californicus* Mann.

By RUSSELL S. LEHMAN, *Assistant Entomologist, Division of Truck Crop and Garden Insects, U. S. Bureau of Entomology*

ABSTRACT

Approximately 150 chemical compounds were tested in the laboratory for their attractiveness to the adults of *Limonius (Pheletes) canus* Lec. and *L. (P.) californicus* Mann. Fourteen of the most attractive compounds, as well as four others, were used in traps in the field. Some of the fatty acids—namely, caproic, lactic, butyric, and valeric—appeared to be sex attractants.

In connection with investgations of wireworms in the Pacific Northwest it was decided to test the attractiveness of a number of essential oils and aromatic compounds to the adults of *Limonius (Pheletes) canus* Lec. and *L. (P.) californicus* Mann. The laboratory experiments were performed under the general direction of M. C. Lane during the winter of 1930–31, at the laboratory of the United States Bureau of Entomology located at Walla Walla, Wash. The field experiments were conducted during the spring of 1931.

Laboratory Experiments—Apparatus

In a circular board 12 inches in diameter eight 1-inch holes were cut equal distances apart and as near the edge of the board as possible. A strip of metal 1 inch wide was placed around the edge of this board. A 16-mesh screen covered the top when the apparatus was in use. A vial, from which the bottom had been removed, was fitted in each hole and covered with paper through which about two dozen pinholes were punched. (Plate 31.)

The normal movement of the beetles, when no compounds were present, was in a circle around the outer edge of the apparatus, with some moving in all directions. The holes were therefore placed as near the outer edge as possible so that the majority of the beetles would come above the compounds.

A 40-watt lamp placed about 8 inches above the apparatus gave the necessary illumination.

Procedure. The beetles were obtained by sifting the soil in the field during November and December and also from soil cages in which large wireworms, ready to pupate, had been placed the previous June.

One of the compounds to be tested was placed on cotton in each of alternate vials; thus there were four vials containing these materials and four were used as controls. The apparatus was then placed above an electric fan and air was blown through the vials to volatilize the materials. The fan was then removed and 25 adult wireworms were placed in the apparatus and left there until definite responses were obtained, or until one hour had elapsed. It was necessary to use a separate apparatus for each sex, as the males seemed to sense the presence of the females after they had been used in a previous experiment.

A compound was considered attractive if any of the beetles that came above it raised their antennae and moved in the direction of the compound, whereas it was considered repellent if any of the beetles moved away from it.

Table 1 shows the response of the beetles to the various compounds. The relative degrees of repellency or attractiveness are indicated as follows:

Proportion of beetles reacting	Degree of attractiveness or repellency
Few	Slight
Half	Fair
Three-fourths	Good
Practically all	Excellent

TABLE 1. REACTION OF MALES AND FEMALES OF *Limonius canus* AND *L. californicus* TO VARIOUS AROMATIC COMPOUNDS

Compound	*Limonius canus*		*Limonius californicus*	
	Male	Female	Male	Female
Acetal (pract.)	Repellent (good)	Slight response	No response	No response
Acetamide (pure)	No response	No response	Slight response	Slight response
Acetic aldehyde	Slight response	Slight response	Attractive (slight)	Slight response
Acetic anhydride	Attractive (slight)	Attractive (slight)	No response	No response
Acetoacetic ester	Slight response	No response	No response	Slight response
Acetone (tech.)	Repellent (fair)	Repellent (fair)	Attractive (slight)	Attractive (slight)
Acetyl-*m*-aminophenol	No response	No response		
Acetyl-*p*-anisidine	No response	No response		
Acetylanthranilic acid	No response	No response		
Acetyldiphenylamine	No response	No response		
Acetylsalicylic acid	No response	No response	No response	No response
Acetyl *m*-toluidine	No response	No response	No response	No response
Allyl ethyl ether	Repellent (excellent)	Repellent (good)	Repellent (excellent)	Repellent (good)
Allyl thiourea	No response	No response	No response	No response
p-Aminobenzoic acid	No response	No response		
o-Aminophenol (pract.)	No response	No response	No response	No response
Aminosalicylic acid (tech.)	Slight response	No response		
Ammonium acetate	Attractive (good)	No response		
Ammonium lactate (pure)	No response	No response		
Ammonium salicylate (U.S.P.)	No response	No response	No response	No response
Ammonium valerate	Attractive (slight)	Attractive (slight)	Attractive (excellent)	Slight response
Isoamyl acetate	No response	No response	No response	No response
n-Amyl acetate (tech.)	Attractive (slight)	No response	Attractive (slight)	Attractive (slight)
Isoamyl alcohol (pract.)	No response	No response	Attractive (slight)	Slight response
sec-Amyl alcohol (pract.)	No response	No response	Attractive (slight)	No response
Amyl benzoate	Slight response	No response	No response	No response
Amyl butyrate	Repellent (good)	Repellent (good)	Attractive (slight)	Slight response
Amyl caproate (pure)	Attractive (slight)	Slight response	Attractive (good)	Attractive (slight)
Amyl formate	Attractive (fair)	Attractive (fair)	No response	No response
Amyl heptoate	Slight response	Slight response	Attractive (fair)	Attractive (slight)
Amyl nitrate	Attractive (slight)	Attractive (slight)		Slight response
Isoamyl nitrite	Attractive (fair)		Slight response	No response

TABLE 1 (Continued)

Compound	*Limonius canus*		*Limonius californicus*	
	Male	Female	Male	Female
Amyl phenylacetate	Slight response	No response	Slight response	No response
Isoamyl phthalate	Slight response	Slight response	No response	No response
Isoamyl propionate (pure)	Slight response	Slight response	Slight response	Slight response
Amyl salicylate	No response	Slight response	Slight response	Attractive (slight)
Amyl valerate	No response	No response	Attractive (slight)	No response
Anethole	Attractive (fair)	Slight response	No response	No response
Anisaldehyde			No response	Slight response
Anisole	Repellent (slight)	No response		
Benzaldehyde	Repellent (good)	Repellent (fair)	Attractive (slight)	Attractive (slight)
Benzyl acetate	Attractive (fair)	Attractive (slight)		
Benzyl alcohol	No response	No response	Attractive (fair)	Attractive (slight)
Benzyl benzoate	No response	No response	No response	No response
Benzyl isobutyrate	No response	No response	Attractive (fair)	Attractive (good)
Benzyl *n*-butyrate	No response	No response	Attractive (slight)	Slight response
Benzyl cinnamate	Slight response	No response		
Benzyl formate	No response	Attractive (slight)	Attractive (slight)	No response
Benzyl phenylacetate	No response	Attractive (slight)	No response	No response
Benzyl propionate	Attractive (slight)	No response	No response	No response
Benzyl valerate	Attractive (fair)	No response	No response	No response
n-Butyl acetate	Attractive (fair)	Attractive (fair)	No response	No response
sec-Butyl acetate	No response	No response	No response	No response
n-Butyl alcohol	Attractive (fair)	Attractive (fair)		
Isobutyl alcohol			No response	No response
Isobutyl aldehyde	Attractive (fair)	Attractive (fair)	Attractive (good)	Attractive (slight)
Butyl anthranilate	No response	Attractive (slight)	Attractive (slight)	No response
Butyl benzoate	Attractive (fair)	Attractive (slight)	Slight response	Attractive (slight)
Isobutyl butyrate	Slight response	Slight response	No response	No response
Isobutyl caproate (tech.)	No response	No response	Attractive (excellent)	Attractive (slight)
n-Butyl caproate (tech.)	Attractive (slight)	Slight response	Attractive (slight)	No response
sec-Butyl carbinol	No response	No response	Repellent (slight)	No response
Butyl cinnamate	Attractive (fair)	Attractive (slight)	Slight response	Slight response

TABLE 1 (Continued)

Compound	*Limonius canus*		*Limonius californicus*	
	Male	Female	Male	Female
Butyl phenylacetate	No response	No response	No response	No response
n-Butyl phenylacetate	Slight response	No response	No response	Slight response
Isobutyl propionate	Slight response	No response	Slight response	No response
n-Butyl propionate	Attractive (fair)	No response	Slight response	No response
Butyl valerate	Repellent (fair)	Repellent (slight)	Attractive (fair)	Slight response
Butyric acid (tech.)	Attractive (excellent)	No response	Attractive (good)	Slight response
Isobutyric acid (pure)	Attractive (fair)	No response	Attractive (good)	Slight response
n-Caproic acid	Attractive (excellent)	Attractive (good)	Attractive (excellent)	No response
n-Capryl alcohol (c.p.)	No response	No response	Slight response	Slight response
sec-Capryl alcohol	Attractive (fair)	Attractive (fair)	No response	Slight response
Caprylic acid	Slight response	No response	Attractive (fair)	No response
Carvone	Repellent (slight)	Repellent (fair)	Slight response	No response
Caryophyllene	No response	No response	No response	No response
Cinnamic aldehyde	Slight response	Slight response	Attractive (slight)	No response
Cinnamyl butyrate	Attractive (excellent)	Slight response	Attractive (slight)	No response
Cinnamyl propionate	Slight response	No response	No response	No response
Citral	No response	No response	No response	No response
Citronella	No response	No response		
Cumene (pure)	Attractive (fair)	Attractive (slight)	Slight response	No response
Cuminol	No response	Attractive (slight)	Attractive (slight)	No response
Cyclohexanol	No response	Repellent (slight)	No response	Repellent (fair)
Diethylamine (pract.)	No response	No response	Attractive (slight)	No response
Diethyl carbinol (tech.)	No response	No response	No response	Slight response
Diethyl phthalate	No response	No response	No response	No response
Dimethylamine (25 per cent H_2O	No response	No response	Attractive (slight)	No response
Ether extract of carrot leaves and stems	Attractive (slight)	Attractive (slight)	No response	Slight response
Ethyl pelargonate	Attractive (good)	Attractive (good)	Attractive (good)	No response
Ethyl *n*-valerate	Repellent (slight)	Repellent (slight)	No response	No response
Ethyl anthranilate	No response	No response	No response	No response

TABLE 1 (Continued)

Compound	*Limonius canus*		*Limonius californicus*	
	Male	Female	Male	Female
Ethyl benzoate	No response	No response	Repellent (good)	No response
Ethyl *n*-butyrate (abs.)	Repellent (slight)	Repellent (fair)	No response	Slight response
Ethyl isobutyrate	Repellent (excellent)	Repellent (excellent)	No response	No response
Ethyl formate	No response	Attractive (slight)	Slight response	Slight response
Ethyl lactate	Repellent (slight)	Repellent (slight)	Attractive (slight)	No response
Ethyl malonate	Repellent (fair)	Repellent (good)	Slight response	No response
Ethyl methyl ketone	Slight response	Attractive (fair)	Attractive (fair)	No response
Ethyl phthallate	No response	No response	No response	Slight response
Ethyl propionate	No response	No response	No response	Slight response
Ethyl salicylate	Attractive (fair)	Attractive (slight)	No response	Attractive (fair)
Eugenol	Attractive (fair)	Attractive (slight)	No response	No response
Furfural	Repellent (excellent)	Repellent (excellent)	Slight response	No response
Geraniol (pure)	No response	No response	Slight response	Slight response
Geraniol propionate	Attractive (slight)	Attractive (fair)	Slight response	No response
Lactic acid (pure)	Attractive (excellent)	Attractive (fair)	Attractive (slight)	Attractive (fair)
Limonene	Attractive (slight)	Attractive (fair)	No response	Slight response
Linaloöl	Repellent (fair)	Repellent (good)	No response	Slight response
Linaloöl butyrate	Slight response	No response	Slight response	Attractive (slight)
Linaloöl cinnamate	Attractive (slight)	No response	Repellent (fair)	Repellent (good)
Linaloöl propionate	Attractive (fair)	Repellent (fair)	Attractive (slight)	Repellent (fair)
Linaloöl valerate	Attractive (fair)	Attractive (fair)	Attractive (fair)	Slight response
Methyl anthranilate	No response	No response	Repellent (good)	No response
Methyl benzoate (pure)	Repellent (slight)	Attractive (slight)	No response	No response
Methyl isobutyrate	Attractive (excellent)	Attractive (good)	Attractive (good)	Attractive (slight)
Methyl isovalerate	Attractive (fair)	Attractive (fair)	Slight response	No response
Methyl lactate	Slight response	Slight response	Slight response	No response
Methyl laurate	Slight response	Slight response	Slight response	Slight response
Methyl salicylate		No response	Attractive (slight)	Attractive (slight)

TABLE 1 (Concluded)

Compound	*Limonius canus*		*Limonius californicus*	
	Male	Female	Male	Female
m-Nitrobenzaldehyde	Repellent (good)	Repellent (good)	Attractive (good)	Slight response
Nitrobenzene	Repellent (good)	Repellent (good)	Repellent (good)	Slight response
Nitromethane (c.p.)	No response	Attractive (slight)	Attractive (slight)	No response
Oil allspice	Attractive (slight)	Attractive (slight)	Slight response	Slight response
Oil anise seed		No response	Attractive (slight)	Attractive (slight)
Oil balm mint	Slight response	Slight response	Slight response	Repellent (slight)
Oil citronella			Slight response	Slight response
Oil bay leaf	No response	No response	Attractive (fair)	Slight response
Oil bergamot	Attractive (slight)	Attractive (slight)	No response	No response
Oil sweet birch	Attractive (slight)	Attractive (slight)	Attractive (fair)	Attractive (slight)
Oil bitter almond	Repellent (slight)	Slight response	No response	Slight response
Oil Bois de Rose femelle	No response	Slight response	No response	No response
Oil cajeput	Attractive (slight)	Attractive (slight)	Slight response	No response
Oil calamus	No response	Repellent (slight)	Slight response	No response
Oil caraway seed	Slight response	Repellent (slight)	Slight response	Slight response
Oil cherry-laurel	Repellent (excellent)	Repellent (excellent)	No response	No response
Oil horsemint	Attractive (slight)	Attractive (slight)	Attractive (good)	Attractive (fair)
Oil juniper wood (artificial)	Slight response	No response	No response	No response
Oil laurel (essential)	Repellent (slight)	Attractive (slight)	No response	Slight response
Oil lemon	Attractive (slight)	Attractive (slight)	Slight response	No response
Oil linaloe Mexican	No response	No response	No response	No response
Oil linseed (raw)	No response	No response	Attractive (slight)	Slight response
Oil mullein	No response	No response	No response	No response
Oil sweet orange	No response	Repellent (slight)	Attractive (slight)	No response
Oil origanum (pure)	No response	No response	No response	Slight response
Paraldehyde	No response	No response	No response	No response

DISCUSSION OF RESULTS. All types of olfactometers used in testing insects have been subject to severe criticism. The same may be true of this apparatus, but it has served the purpose for which it was constructed—namely, the selection of the most attractive substances for use in the field. Although there was some intermingling of odors within the apparatus, the fact that in some cases one compound was attractive while another in the apparatus at the same time was repellent indicated that the odors were distinct.

The fatty acids lactic, butyric, and caproic appeared to be sex attractants, as indicated by the following observations: When the male beetles came above any of these acids, especially caproic acid, they became much excited and extended their genitalia. The males would get on top of one another and try to mate. In one instance there were five piled up in this way, each having the genitalia extended except the one on the bottom. The fifth one caused the pile to topple over.

FIELD EXPERIMENTS. Those compounds that were considered excellent attractants and a few that were considered good were used in the traps placed in the field. Valeric acid, peach flavor, nectar, and oil of onion were not available for the laboratory tests, but the writer thought it advisable to use these materials in the field for the following reasons: Valeric acid is a fatty acid; the beetles are known to feed on the flowers of fruit trees; and the larvae are found in large numbers in onion fields.

APPARATUS. The traps used in the field experiments were made from 2-pound coffee cans. (Plate 31.) The bottom of each can was cut clean and its position reversed so that it became the top of the trap. A 16-mesh wire disk, with a hole in the center large enough to admit the end of a funnel, was soldered across the trap about one-third of the distance from the top. A funnel was placed in the trap flush with the top and protruding through the wire-mesh screen. The bottom of the trap could be removed to collect the beetles.

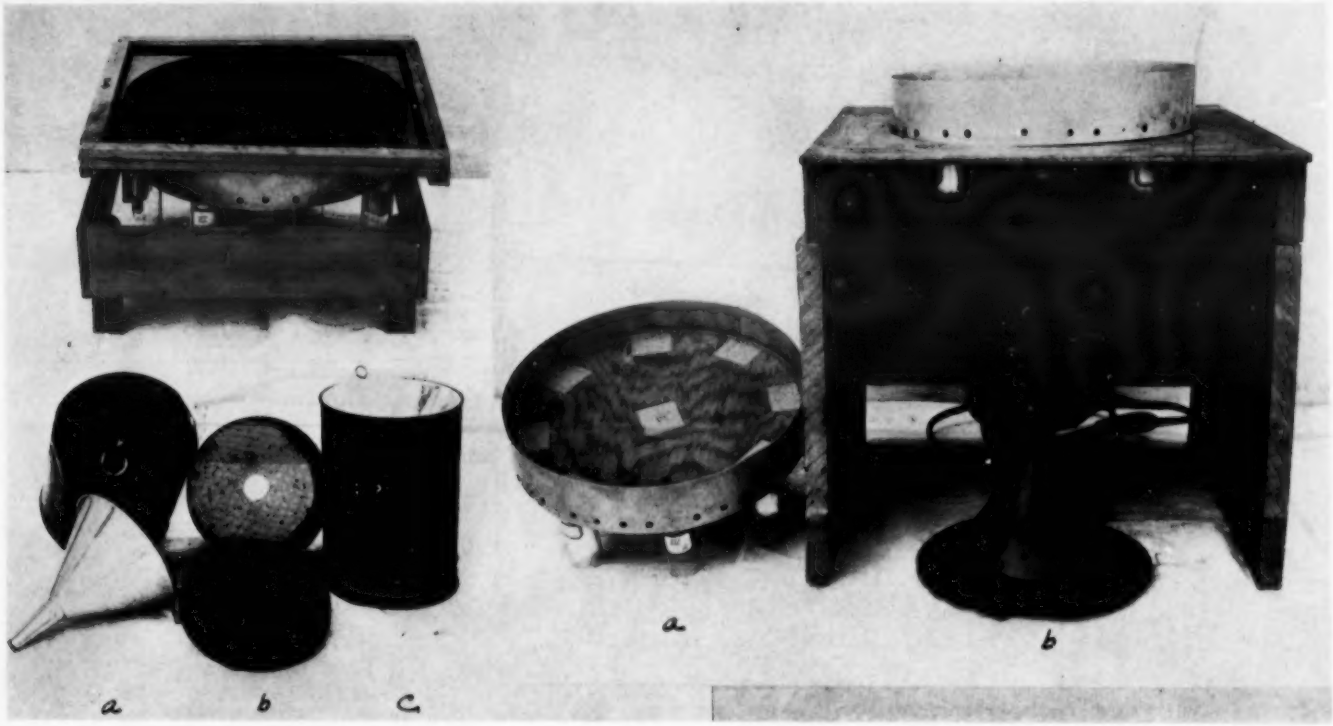
PLATE 31

1.—Olfactometer used in laboratory experiments to determine the attractiveness of certain compounds to adults of the wireworms *Limonius canus* and *L. californicus.*

2.—(*a*) Top view of olfactometer showing perforations above the vials; (*b*) method used to volatilize the compounds and to aerate the apparatus after each experiment.

3.—Traps used in field experiments with attractants for adults of *Limonius canus* and *L. californicus:* (*a*) Bottom view of trap showing protruding funnel; (*b*) view from top showing screen disk with hole for funnel; (*c*) assembled trap.

Plate 31



1

3

2

The cost of materials for each trap was less than 10 cents.

PROCEDURE. The material to be tested was usually dissolved or emulsified to a 5 per cent solution or emulsion with water, although a more dilute solution was used in a few cases. The solution or emulsion was thoroughly mixed with bran until the bran was quite moist. The mixture was then placed on the wire-mesh screen and the funnel was put in position. The odor from the compound went to the bottom of the trap and then up through the funnel.

Most of the traps were hung on posts at various heights above the ground up to 6 feet. A few were buried so that the top of the trap was flush with the ground and some were placed in cherry trees at heights up to 9 feet.

During the first month the traps were in the field they were examined every day. Later they were examined every other day. Table 2 summarizes the results of the field experiments.

TABLE 2. NUMBERS OF ADULTS OF WIREWORMS ATTRACTED TO DIFFERENT MATERIALS IN TRAPS IN THE FIELD, 1931

Attractant	*Limonius canus*		*Limonius californicus*		Total	Number of traps	Average number of beetles per trap
	Male	Female	Male	Female			
Caproic acid	2,745	148	8	0	2,901	32	90.65
Butyric acid	1,589	156	5	1	1,751	34	51.50
Valeric acid	837	105	4	0	946	23	41.13
Ethyl salicylate	63	23	0	0	86	3	28.66
Peach flavor	72	7	1	0	80	3	26.66
Isobutyl aldehyde	45	6	1	0	52	3	17.33
Lactic acid	238	10	0	0	248	18	13.80
Oil horsemint	68	4	0	0	72	5	14.40
Isobutyl caproate	42	11	0	0	53	5	10.60
Ethyl pelargonate	163	34	3	2	202	29	6.96
Cinnamyl butyrate	49	7	1	0	57	9	6.33
Oil of onion	17	4	2	1	24	6	4.00
Amyl caproate	7	0	0	1	8	3	2.66
Methyl isobutyrate	9	0	0	0	9	4	2.25
Geraniol	14	4	0	0	18	8	2.25
Ammonium acetate	3	0	0	0	3	2	1.50
Ammonium valerate	1	0	0	0	1	1	1.00
Nectar	0	0	0	0	0	1	0.00
Total or average	5,962	519	25	5	6,511	189	34.45

DISCUSSION AND CONCLUSION. The first appearance of the beetles in the field was noticed in rhubarb on March 20, 1931. This appearance was slightly abnormal, since the rhubarb had been forced with warm running water from an artesian well. The beetles did not appear in other localities until a few days later.

At first the traps on the surface of the ground contained the most beetles. Later, when the beetles became more active and were flying freely, there were more in the traps at 3 to 6 feet above the ground.

Inasmuch as the beetles collect on the rhubarb flower heads to feed, the largest numbers were caught in the rhubarb fields. A large number were also obtained in a cherry orchard in which spinach was growing.

The field experiments bore out the indications in the laboratory experiments that butyric, caproic, and lactic acids are sex attractants. Valeric acid was also found to be a sex attractant.

Since the majority of beetles caught in the traps were males and these were only a small percentage of the total, the traps cannot be considered as a means of control. This investigation will be continued in the hope that better attractants may be found.

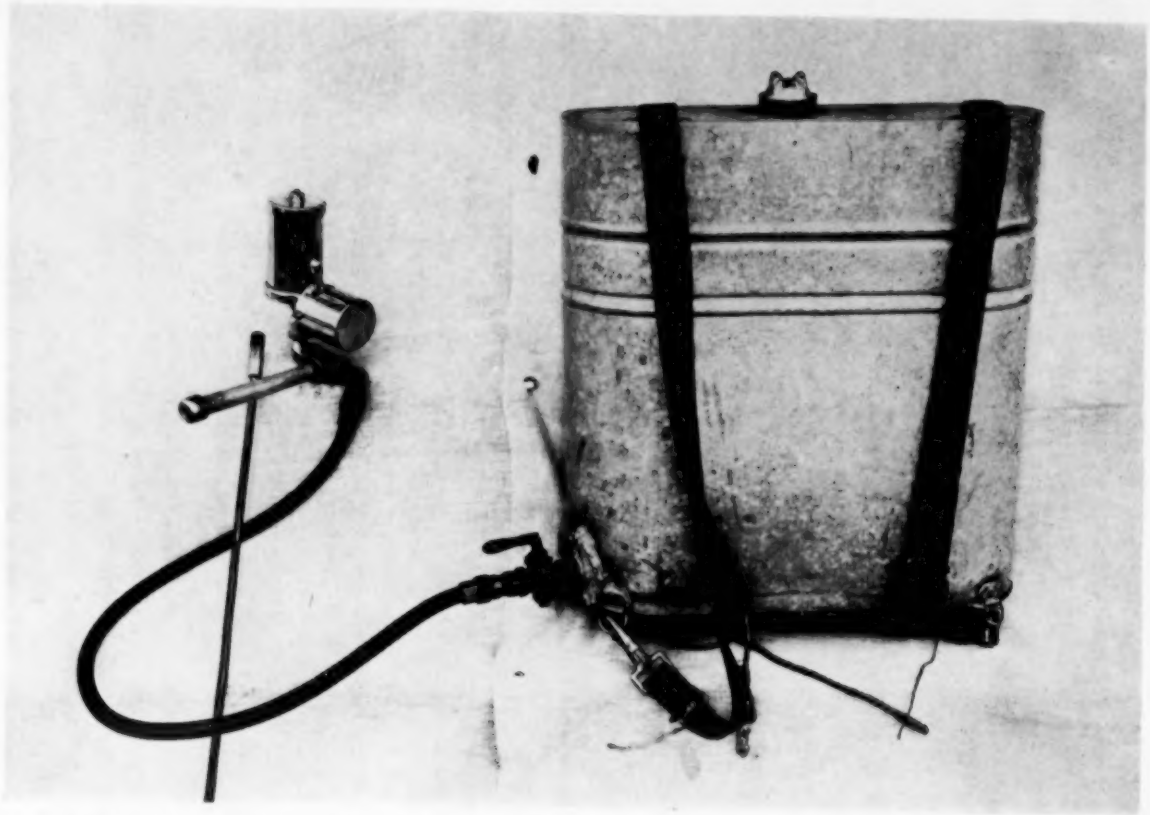
CARBON DISULPHIDE AS A CONTROL FOR WIREWORMS

By M. C. LANE, *Associate Entomologist*, and K. E. GIBSON, *Junior Entomologist*, *Division of Truck Crop and Garden Insects, U. S. Bureau of Entomology*

ABSTRACT

The results of several seasons' work with carbon disulphide as a soil fumigant against wireworms are reported. All the experimental work was done out of doors in the infested fields. Data are presented to show that carbon disulphide can be used as a practical and efficient control for wireworms in the soil under certain conditions. These conditions are a loose, damp soil, a diffusion distance of 17 inches or less, and a dose of at least 1 ounce. A good kill of wireworms was obtained by placing 1-fluid-ounce doses of carbon disulphide in holes 4 inches deep and 18 inches apart, and fair control was obtained by spacing the same dose 24 inches apart. Whether the difference in kill justifies the increased cost of the applications 18 inches apart is for the individual to decide. For the best diffusion of the carbon disulphide in the surface layer of soil, the soil should be prepared by plowing.

Carbon disulphide has been used as a soil fumigant in the control of wireworms for the past four seasons in the Yakima and Walla Walla valleys of Washington. The experimental work described in this article has been carried on, in cooperation with farmers, in fields devoted to raising truck crops under irrigated normal cropping conditions. Two brands of carbon disulphide have been used, a material 95 per cent pure with 5 per cent of "activators" to make it less volatile and slower acting, and the ordinary commercial 99.9 per cent pure carbon disulphide. No difference in kill of wireworms was noted between these two brands.



The knapsack canteen and automatic valve for applying carbon disulphide to soil with dropping tube disconnected

The factors of temperature, moisture, and texture and compactness of soil, both at the time of treatment and subsequent thereto, were all so variable and mostly beyond control that it has not been practical in all cases to bring them together for purposes of comparison. However, some of the factors, such as moisture and temperature in connection with the use of carbon disulphide, have been worked out under controlled conditions in the laboratory and the results will be reported in a subsequent paper. This article will summarize only the results of actual field tests, showing some of the limits of the use of carbon disulphide in the soil, and indicate its practical use as a control for wireworms within these limits.

APPARATUS AND METHODS. Carbon disulphide was applied to the soil from a knapsack carrier and dispensed through an automatic valve. (Plate 32.) The carrier consisted of a 5-gallon can made to fit on the operator's back, to which was attached a shut-off and a short length of flexible metal hose to carry the liquid to the automatic valve. This valve was of metal and of a float-ball type adjustable to dump from one-half ounce to 4 fluid ounces[1] at each throw of the lever. A copper tube was attached to the lower opening of the valve to allow the materal to be carried into the soil with little escape of the gas.

Plots to be treated were marked off into squares with an adjustable marker, and at the intersections holes for the reception of the carbon disulphide were punched to a depth of 4 inches. Immediately after application of the carbon disulphide the holes were filled with damp soil by the foot of the operator.

Two methods were used to obtain the kill of wireworms. The first method consisted of burying cylindrical brass-screen cages (1 by 8 inches) containing wireworms, wheat, and soil vertically in the treated and the untreated plots. These cages were inserted at the greatest diffusion distance or equidistant from three or four surrounding doses of carbon disulphide. After five days' exposure they were removed from the soil and the percentage kill of wireworms was recorded. Plenty of time was allowed for the recovery of inactive wireworms.

The second method consisted of sifting 1-cubic-foot samples of soil at random throughout the treated and untreated lots both before and after the experiment. The soil was sifted through screens that retained all but the very smallest wireworms, and at least 10 siftings were made per plot immediately after treating and at frequent intervals up to a year

[1]Ounces of carbon disulphide in this paper refer to fluid ounces by measure in all cases.

thereafter. Soil moisture and temperature records were made at all stages of the experiment, especially at the time of treatment with carbon disulphide.

Plots treated in this way varied in area from a few hundred square feet to one-quarter of an acre, with an average of 1,000 square feet.

EFFECT OF SIZE OF DOSE AND DISTANCE BETWEEN DOSES ON KILL OF WIREWORMS. The size of the dose of carbon disulphide necessary to diffuse in lethal quantity to kill wireworms at different distances in the soil was one of the first problems undertaken. The results of several seasons' work have been brought together on a percentage basis in Tables 1 and 2.

Table 1 summarizes the results obtained from 43 experiments in which the wireworm kill was checked by the cage method after five days' exposure to the carbon disulphide in the soil. Four different doses of carbon disulphide were tried and six different sizes of squares were used in marking the land and spacing the doses. The cages of wireworms exposed to the gas were placed in holes bored in the centers of the squares equidistant from four doses of carbon disulphide, or at the greatest distance the gas would have to diffuse to fill all the soil interspaces. Therefore, these experiments should show the percentage of kill that could be expected at the greatest distance from the point where the doses were placed. This would then be the minimum expected kill. Wireworms from the same lots and of the same ages were placed in soil cages outside of the treated areas, thus allowing for a check on the normal mortality, which, as well as cannibalism where it occurred, was taken into account in reporting these results. In most cases 10 wireworms were used per cage and there were at least 10 cages per experiment.

TABLE 1. WIREWORMS KILLED IN CAGES PLACED EQUIDISTANT FROM FOUR DOSES OF CARBON DISULPHIDE (SQUARE SYSTEM OF MARKING)

Distance between doses	Greatest diffusion distance	Kill of wireworms caused by different doses of carbon disulphide			
		¾ ounce	1 ounce	1¾ ounces	2¼ ounces
Inches	*Inches*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
12	8.5	98.3	—	—	—
18	12.7	86.6	98.8	98.0	—
24	17.0	25.6	68.2	61.0	97.0
30	21.0	0.8	9.5	1.7	61.3
36	25.0	0.0	—	3.8	1.7
42	30.0	—	—	0.0	0.0

It will be seen from Table 1 that the best kills were obtained at the 8.5-inch and the 12.7-inch diffusion distances, or where the 12-inch and 18-inch square systems of spacing the doses were used. The 1-ounce

dose gave better kills than the three-fourths ounce dose except in the case of the shortest diffusion distance. When the greatest diffusion distance was increased to 17 inches by spacing the doses 24 inches apart, the percentage kill dropped off. However, the percentage of kill did not in all cases increase proportionately as the dosage increased.

In Table 2 are shown the results of the second method of checking the kill of wireworms. The percentage of kill in this case was based on populations taken with the sifting machine before and not sooner than five days after treating with carbon disulphide. Data from 29 experiments are presented in this tabulation. Here again the best kill was obtained with the 12-inch and 18-inch spacings of the doses and with the 1-ounce dose However, in general a much higher percentage of kill was obtained than is shown in Table 1. This is to be expected where the checking was done at random over the entire plot and not taken just at the greatest diffusion distance of the gas.

TABLE 2. CONTROL OF WIREWORMS BASED ON COMPLETE POPULATIONS (SQUARE SYSTEM OF MARKING)

Distance between doses	Kill of wireworms caused by different doses of carbon disulphide			
	¾ ounce	1 ounce	1½ ounces	2¼ ounces
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*
12	100.0	—	—	—
18	68.3	96.3	85.3	—
24	62.0	36.8	65.9	77.9
30	10.8	—	85.7	31.8
36	0.0	—	77.7	71.4
42	—	—	0.0	79.2
48	—	—	—	33.3

The data presented in these two tables definitely show that there is a limit to the ability of carbon disulphide gas to diffuse in the soil in quantities lethal to wireworms.

EFFECT OF TREATMENTS BEFORE AND AFTER IRRIGATION OF SOIL. In order to test the effect of treating with carbon disulphide before and after irrigation, four plots 35 by 35 feet were marked off in a field badly infested with wireworms. Three of these plots were treated with 1-ounce doses of carbon disulphide. Instead of being marked off in 24-inch squares as formerly, the land was marked off 24 inches one way and 21 inches the other. Doses were spaced 24 inches along one line and staggered half way on the next line. In this way the doses were placed on a triangular system, making a shorter distance for the gas to diffuse to fill all the soil interspaces, but increasing the doses per plot. The greatest diffusion distance by this method is only 14 inches, as compared

TABLE 3. EFFECT OF IRRIGATION, BEFORE AND AFTER TREATMENT OF SOIL WITH CARBON DISULPHIDE, ON POPULATIONS OF WIREWORMS

Relation between time of irrigation and treatment	Average conditions in surface foot of soil: Temperature Before	Temperature After	Moisture Before	Moisture After	Populations[1]: Active wireworms per cu. ft. Before	After 10 days	After 3 months	Reduction or control After 10 days	Reduction or control After 3 months
	°F.	°F.	Per cent		Number	Number	Number	Per cent	Per cent
Treated dry, not irrigated	82	78	15.19	16.91	8.92±2.34	0.64±.20	0.28± .24	92.8	96.9
Treated dry and then irrigated	79	80	15.91	20.08	10.64±4.02	0.16±.15	0.08± .11	98.5	99.9
Irrigated before treating	74	73	23.79	17.02	10.68±2.82	0.12±.12	0.12± .12	98.9	98.9
Check	82	—	14.54	——	9.80±2.00	————	9.12±2.46	——	6.9

[1]Populations were found statistically from sifting records and twice the standard errors calculated.

with 17 inches where 24-inch squares are used. The wireworm population of the plots was obtained by taking 25-square-foot unit siftings before treating, 10 days after treating, and 3 months after treating. The fourth plot was not treated or irrigated and was used as a check.

The results are shown in Table 3. The irrigated plots gave a slightly better kill than the unirrigated plot. There was no appreciable difference between irrigating before and after introduction of carbon disulphide. However, there was little difference in the percentage of moisture with various plots. The soil was of fine sandy loam type and evaporation was rapid during the experiment. The experiment shows a good kill, probably aided primarily by the high temperature.

DIFFUSION OF CARBON DISULPHIDE IN SOIL OF VARIOUS TYPES. In order to determine the greatest distance horizontally and vertically that carbon disulphide will diffuse in soil of various types and degrees of compactness, another set of experiments was tried. Individual cages for the wireworms were devised for these experiments. These cages were three-fourths of an inch by 2 inches and were made of brass screen with soldered tin bottoms and Number 8 corks fitted in the tops. One healthy wireworm with soil was placed in each cage. Six of these cages were placed in a hole made with a three-fourths-inch soil auger to a depth of 18 inches in the soil. The centers of these six cages containing wireworms were placed at approximately the following depths: 1½, 4½, 7½, 10½, 13½, and 16½ inches. Ten sets of six cages were placed in as many holes at the greatest diffusion distance from the carbon disulphide in each plot treated. Three different fields were marked off by different methods to make a series of greatest diffusion distances. Two of the fields contained soil of a fine sandy-loam type. One of these was irrigated, plowed 10 inches deep, and dragged lightly two days previous to treating; the other had not been cultivated and was packed by recent rains. The third field was of a clay-loam type, and was plowed 10 inches deep and dragged lightly the day before it was treated. Carbon disulphide was used at the rate of 1 ounce per dose in all three plots.

The results are presented in Table 4. There was not much difference in percentage kill of wireworms in the three types of soil. The clay loam shows about as good a kill at all depths as the fine sandy loam. The packed soil did not allow the gas to diffuse quite so well as the looser soils. Differences in temperature and moisture were probably important in accounting for some of the irregularity.

The data from this same experiment are shown in another way in

TABLE 4. TOTAL PERCENTAGE OF WIREWORMS KILLED IN CAGES AT ALL DEPTHS

Distance between doses *Inches*	Greatest diffusion distance *Inches*	Fine sandy loam Plowed 10 inches deep *Per cent*	Fine sandy loam Packed by rains *Per cent*	Clay loam plowed 10 inches deep *Per cent*
18, triangular	10.5	92	87	93
18, square	12.7	100	77	80
24, triangular	14.0	40	30	85
24, square	17.0	85	5	25
30, triangular	17.5	8	—	7
Checks	—	2	0	0
Average temperature of surface foot		72°F.	62°F.	61°F.
Average moisture of surface foot		12.34 per cent	25.46 per cent	28.34 per cent

Table 5 and are presented graphically in Figures 62 and 63. Here the percentage kill is shown by depths for each system of marking and dif-

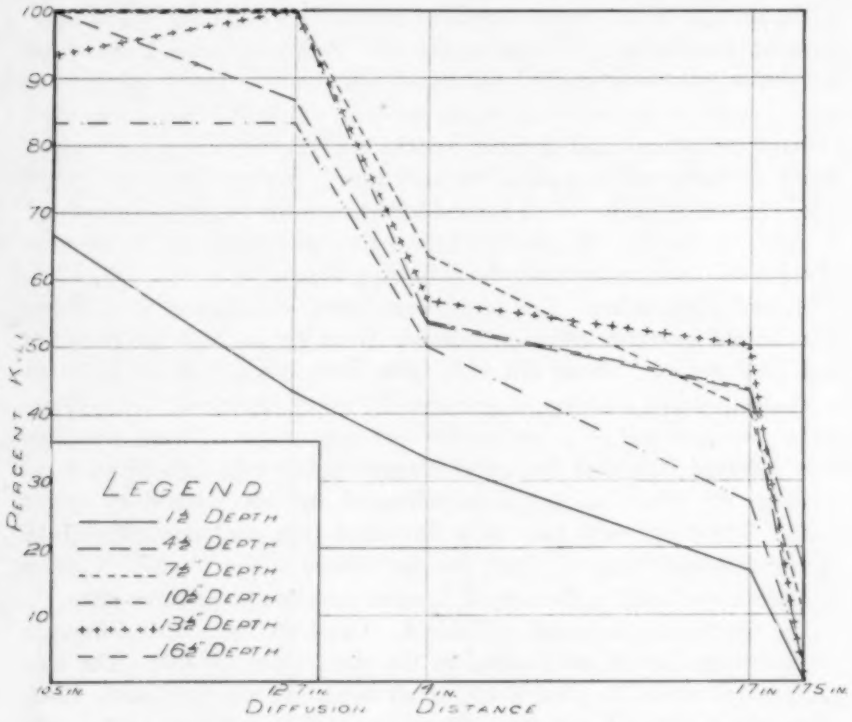


Fig. 62.—Percentages of wireworms killed in cages at various depths according to greatest diffusion distance.

fusion distance. Three fields are averaged as one, the depth curve of percentage kill being the same for all. In Table 5 and Figure 63 it is

seen that the poorest kills are obtained near the surface (1½ inches) and at the greatest depth (16½ inches) in all cases. This is to be expected inasmuch as carbon disulphide is heavier than air and diffuses

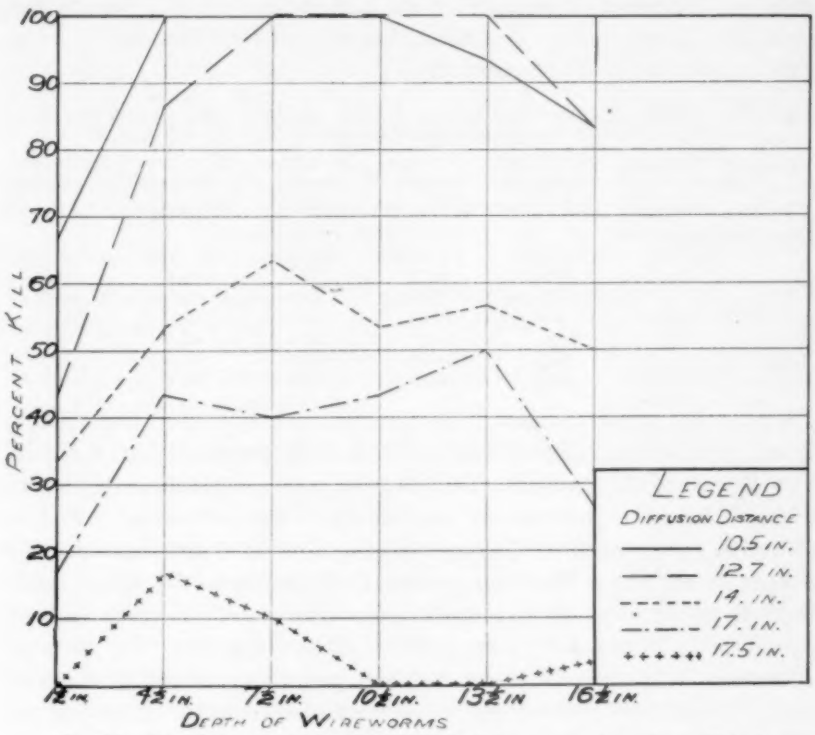


Fig. 63.—Percentages of wireworms killed in cages at various diffusion distances according to depth.

more quickly downward, missing to a certain extent the point midway between the doses near the surface. The lower depths are more closely packed and usually too wet for good diffusion. However, as the majority of wireworms are found in the surface foot of soil during the active season, the results shown here should be accurate for practical purposes.

The surface kill is greater when determined from the total populations of wireworms, as the cage tests are made only at the greatest diffusion distances and for five days' exposure. It does not seem practicable to place the carbon disulphide in holes shallower than 4 inches, as the material must be placed in the damp soil and immediately covered and

stamped down with more damp soil in order to keep the gas in and prevent waste. A further study of Figures 62 and 63 shows that there is a steady decrease in percentage of kill as the diffusion distance increases. Diffusion distances of both 10.5 inches and 12.7 inches gave good kills of wireworms. Diffusion distances of 14 inches and 17 inches gave an average of 50 per cent kill.

TABLE 5. PERCENTAGE OF WIREWORMS KILLED IN CAGES ACCORDING TO DEPTH AND DIFFUSION DISTANCE

Distance between doses	18 inches, triangular	18 inches, square	24 inches, triangular	24 inches, square	30 inches, triangular
Diffusion distance	10.5 inches	12.7 inches	14 inches	17 inches	17.5 inches
Depth of cage in soil	Kill of wireworms				
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1½	66.6	43.3	33.3	16.6	0.0
4½	100.0	86.6	53.3	43.3	16.6
7½	100.0	100.0	63.3	40.0	10.0
10½	100.0	100.0	53.3	43.3	0.0
13½	93.3	100.0	56.6	50.0	3.3
16½	83.3	83.3	50.0	26.6	0.0

PRACTICAL APPLICATIONS. The practical use of carbon disulphide in treating wireworm-infested fields is limited by the condition of the soil and the cost of the material. Table 6 gives some comparative data on the cost of different methods of application. The individual will have to decide for his own conditions, both as to his field and finances, what dosage he will use. The 1-ounce dose at 24 inches on the square would seem to be the most practical for average conditions. There is less confusion in following the square method of marking and, with favorable conditions of temperature and soil, the percentage of kill is relatively high. This method of treatment is recommended for small isolated garden plots, as it will reduce the numbers of wireworms materially for several seasons.

TABLE 6. DATA FOR FIELD USE OF CARBON DISULPHIDE FOR THE CONTROL OF WIREWORMS

Distance between doses	Greatest diffusion distance	Doses per acre	Quantity per acre	Cost per acre
Inches	*Inches*	*Number*	*Pounds*	
12, square	8.5	43,560	3,403	$187.31
18, triangular	10.5	33,926	1,790	98.58
18, square	12.7	19,360	1,513	83.24
24, triangular	14.0	12,446	973	53.52
24, square	17.0	10,890	851	46.83
30, triangular	17.5	8,043	628	34.58

1932 Prices F.O.B. Stege, Calif.

55-gallon drum (550 pounds) ..... $0.0525 per pound
10-gallon drum (100 pounds) ..... .0675 per pound
5-gallon drum (50 pounds) ..... .0675 per pound

Ten gallons, or 100 pounds, of carbon disulphide, when used in 1-ounce doses on the 24-inch square, will treat a plot approximately 5,000 square feet at a cost of $6.75 for the material. Two men can mark off and treat approximately 1,800 square feet per hour, and the cost of this labor should be added to the cost of the material.

THE EFFECT OF SULPHUR ON WIREWORMS

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Abstract

Claims have often been made that the application of sulphur to the soil will control wireworms. Two sets of field experiments were carried on for four year periods, in which up to 1000 pounds of sulphur per acre per year were applied. There was a decided reduction of the pH of the soil but no noticeable reduction in the wireworm population.

At various times claims have been made that the use of sulphur in the soil would control wireworms. Such claims, however, have not been supported by experimental evidence. While engaged in an investigation of wireworms in southern California, an excellent opportunity was presented for an extensive field test of this material. Mr. F. H. Ernst, Assistant Farm Advisor of Los Angeles County, was carrying on a series of tests with sulphur to control potato scab and the authors arranged to cooperate with him in order to obtain data on any possible effect on wireworms. Bulger (1) has shown that soil rendered acid by sulphur or sulphuric acid did not affect wireworms adversely when the acidity was less than that represented by a pH of 2.7, but when it was greater than a pH of 1.9, soils were very toxic. A considerable part of Bulger's experiments were in the laboratory and of short duration, while those reported here are field experiments covering a period of four years.

Eight plots of one-fourth acre each had been established in 1926 with plots 5 and 8 each receiving 500 pounds of finely ground sulphur (Table 1). Plots 2, 4, 5, and 8 each received 800 pounds in the spring and summer of 1927 and again in the spring of 1928. Finally plots 1 and 6 received 1,200 and 800 pounds, respectively, in August, 1928. The sulphur was applied with a fertilizer drill and then plowed under. During the course of the experiment a spring and a fall crop of potatoes was grown each year.

Beginning with the summer crop of 1928, four crops of potatoes were examined for wireworm damage. No attempt was made to determine the degree of damage but a potato was classed as infested if it had one or more wireworm punctures. Three sacks of potatoes were examined from each plot. At harvest time soil samples were taken from three points in each plot and the pH determined, the figures given being the average of the three readings. The pH determinations for 1928 were made colorimetrically, but all others were electrometric. Table 1 gives the results.

TABLE 1. EFFECT OF THE APPLICATION OF SULPHUR TO SOIL INFESTED WITH WIREWORMS

Plot No.	Total pounds sulphur applied	pH of soil					Per cent wireworm-damaged potatoes				
		July, 1928	Apr., 1929	Aug., 1929	Apr., 1930	Ave.	July, 1928	Apr., 1929	Aug., 1929	Apr., 1930	Ave.
8	2,900	4.5	5.30	4.91	4.99	4.92	25.6	7.1	34.3	18.6	21.4
7	——	6.9	6.80	6.49	6.18	6.59	19.4	23.8	45.0	19.	26.8
6	800	6.4	5.67	5.52	5.64	5.81	20.4	13.7	29.0	10.	10.0
5	2,900	4.3	4.60	5.22	5.16	4.81	17.8	21.7	24.3	24.5	22.1
4	2,400	3.8	4.73	4.96	4.77	4.58	19.1	7.4	25.6	22.6	18.6
3	——	6.9	7.11	7.25	6.35	6.90	42.3	2.8	32.1	14.3	22.8
2	2,400	5	4.91	5.02	5.58	5.01	24.7	1.3	32.7	7.5	16.5
1	1,200	6.3	5.12	5.70	5.56	5.67	26.2	3.3	16.	7.	15.6
Ave. for sulphur plots.....		5.0	5.01	5.22	5.28		22.3	8.	26.9	15.0	20.8
Ave. for checks		6.9	6.85	6.87	6.26		30.8	11.	38.8	16.5	24.8

Plots 5 and 8 each received 500 pounds in August, 1926.
Plots 2, 4, 5 and 8 each received 800 pounds in March and July, 1927, and March, 1928.
Plot 1 received 1,200 pounds in August, 1928.
Plot 6 received 800 pounds in August, 1928.

The pH readings show definitely that the sulphur applications increased the soil acidity and also that the plots with the greater quantities of sulphur were the more acid.

However, no such correlation exists between sulphur application and the percentage of wireworm-damaged potatoes. Although the check plots average a little higher in percentage of injury than the sulphured plots, the reductions in the latter are in no way proportional to the quantity of sulphur applied. In addition, there was no progressive decrease in damage during the course of the experiment.

Since wireworm activity varies with weather conditions, comparison must be made of crops grown in corresponding seasons. Comparing the summer crops, all plots of 1929 show an increased infestation over those of 1928 except No. 3, a check, and No. 1, to which 1,200 pounds of

sulphur was applied. Comparing the winter crops harvested in April, the 1930 crop had a greater infestation than that of 1929 in each treated plot except No. 6, which had 800 pounds of sulphur. Unpublished notes show that under ordinary field conditions, this species (*Limonius californicus* Mann.) reaches maturity during the third summer of its larval life. Since this experiment continued for four years, the results indicate that repeated applications of sulphur did not materially reduce wireworm damage to potatoes grown in the infested soil.

TABLE 2. SHOWING THE EFFECT OF THREE YEARLY APPLICATIONS OF SULPHUR ON pH OF THE SOIL AND WIREWORM DAMAGE TO POTATOES

Pounds per acre applied each year	1928		1929		1930	
	pH	Per cent damaged	pH	Per cent damaged	pH	Per cent damaged
300	8.2	66.4	7.45	78.4	7.57	36.5
checks	8.5	72.1	7.67	76.5	7.75	39.6
450	8.1	50.3	7.67	80.9	7.28	32.9
checks	8.4	44.9	7.61	80.3	7.17	41.5
600	7.6	39.3	6.66	80.8	6.45	35.3
checks	8.3	32.6	7.52	75.4	7.85	30.3
800	6.5	32.8	6.50	72.6	6.33	33.1
checks	8.3	38.3	7.54	68.2	7.78	28.2
1,000	6.8	28.9	5.65	58.5	5.61	37.2
checks	8.4	30.3	7.91	54.8	7.65	33.7
Ave. for sulphur plots	7.4	43.5	6.78	74.2	6.64	35.0
Ave. for checks plots	8.3	43.6	7.65	71.0	7.64	34.4

Through the cooperation of the Western Sulphur Company, another field experiment was undertaken. Two acres were divided into 20 plots, 10 of which were treated and 10 left as checks. Sulphur was applied at the rate of 300, 450, 600, 800, and 1,000 pounds per acre in duplicate plots and each plot had a check on either side. Sulphur was applied and plowed under, and potatoes were planted each year in April. The crop was harvested in August, at which time 100 potatoes from each of three points in each plot were examined for wireworm damage. Soil samples were also taken at this time and the pH determined electrometrically.

Table 2 shows the results for three years. There is a general increase in the infestation in 1929 and a decrease in 1930, but it occurs in checks as well as treated plots. An increased acidity is again noticed in the sulphured plots, small where only 300 pounds of sulphur per acre was used and marked in the 1,000-pound plots. Differences in wireworm damage is small, and while these differences are probably due to plot variation or random sampling, the sulphured plots in most cases show a

slightly higher percentage of wireworm-damaged potatoes than the untreated plots.

No crop was grown in 1930, but to determine if there might have been a cumulative effect by that time, a wireworm population count was made by drilling wheat in rows across the plots and at nine and fifteen day intervals later examining several 10-foot sections of these rows. Table 3 shows the results.

TABLE 3. EFFECT ON WIREWORM POPULATION OF THREE YEARS' APPLICATION OF SULPHUR TO THE SOIL

(Applications made in 1928, 1929, and 1930; wireworm population count in 1931).

Pounds sulphur per acre per year	Average number of wireworms per 10 feet of bait row
300	7
checks	8.6
450	19
checks	10.7
600	13.5
checks	8
800	9
checks	5.7
1,000	4.5
checks	5

While the number of wireworms recovered is comparatively small, no material toxic effect of the sulphur was shown even where 1,000 pounds per acre had been applied successively for three years. As in the previous year, the wireworms in the sulphured plots actually outnumbered those in the untreated plots.

These two experiments, carried on for four years, show that sulphur, applied in the soil in quantities up to 1,000 pounds per acre per year, has little of no effect on wireworm damage or population, even though a decided increase in the acidity of the soil was maintained during that period.

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INSECTS FOUND ON PEA FIELDS IN THE WILLAMETTE VALLEY, OREGON, AFTER HARVEST

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ABSTRACT

The numbers and kinds of insects found on pea fields after harvest in the Willamette Valley are considered in this paper. The average number of insects were found to decrease each day after harvest. Of the total number of insects other than pea weevils, 76 per cent were injurious, 22 per cent were beneficial and 2 per cent were of unknown economic importance.

In order to ascertain the effect of burning, one of the methods recommended for the control of pea weevils in the Willamette Valley, not only on the pea weevil but also on other insects, it was necessary to know the kinds and numbers of insects that are found in the pea fields after harvest. It has been shown that large numbers of pea weevils may remain on the ground after the pea crop has been harvested,[1] but there appears to be no record as to the other insects which may also be present at this time. To gain this information the writers collected and counted the insects found on 78 plats, each 10 feet square, in 20 fields in widely separated parts of the Willamette Valley. From these counts the numbers of insects per acre were computed. All straw and litter was carefully examined and removed and the surface of the ground was thoroughly inspected. No attempt was made to collect aphids and insects of the subclass Apterygota, although a few of the former and many of the latter were observed.

Besides pea straw these plots usually contained oat straw and weeds, especially cornflower (*Centaurea cyanus* L.) and Canadian thistle (*Cirsium arvense* (L.) Scop). The straw and practically all of the weeds were well ripened and dry before the peas were threshed. In some fields the crop was hauled away to be threshed, but in other fields the threshing was done with pick-up machines and the straw was scattered over the ground.

It was found that many of the insects left the fields within a few days after the crop had been removed. There is little doubt but that the migration of the insects was due more to the hot sunshine of July and August than to the lack of food. In fields threshed with pick-up machines there was usually a good covering of straw. There was a more rapid migra-

[1]Larson, A. O. Pea weevil Control in the Willamette Valley. Oreg. Agr. Expt. Sta. Circ. 99, 12 p. 1931.

tion from fields that had been threshed with a stationary thresher, where the stubble was short and practically no straw was left to cover the ground.

The number of insects from 6 fields in which collections were made on the day of harvest or 1 day later averaged 12,657 per acre. From the 15 fields in which collections were made within the first 3 days after harvest there was an average of 8,125 insects per acre, but in the 9 fields where the insects were collected on the second and third days after harvest the average number was only 5,104 per acre. The insects collected from 5 fields 4 to 9 days after harvest averaged only 1,566 per acre. The average per acre for the 78 plats was 5,847. These figures indicate that the number of insects to be found on a pea field decreases with each succeeding day after harvest.

A total of 1,048 specimens of insects were collected. Nearly two-thirds, or 661 of these, were Coleoptera. Of these, 324 were the very injurious species, *Diabrotica soror*. This insect was found to be very generally distributed over the valley. In one plat 80 *D. soror* were collected and in another 57, or equivalent to 34,848 and 24,829 per acre, respectively. The average number per acre for the 78 plats was 1,809. In the section where such large numbers of *D. soror* were found, considerable damage was being done to gardens, especially to growing beans.

Blapstinus gregalis (Tenebrionidae), another injurious beetle, was also much in evidence. As many as 10 in a plat, or 4,356 per acre, were found. The average for all plats was 525 per acre.

Curculionids were not so evenly distributed and averaged only 273 per acre for all plats, but 27 *Sitona hispidula*, or the equivalent of 11,761 per acre, were collected from one plat.

Beneficial beetles were represented by coccinellids, carabids, staphylinids, dermestids, and melyrids. The number of the coccinellids collected was 103, equivalent to 575 per acre. Twelve, or at the rate of 5,227 per acre, was the greatest number found on one plat. Only 35 carabids, or an average of 195 per acre, were collected. These did not appear to be evenly distributed, as 12, or 5,227 per acre, were collected from one plat.

From the 78 plats an estimated average of 2,612 injurious beetles per acre were collected—1,809 *D. soror*, 525 *B. gregalis*, 273 curculionids, and 5 elaterids. There were also 1,059 beneficial beetles per acre—575 coccinellids, 195 carabids, 150 melyrids, 117 staphylinids, and 22 dermestids.

There were 325 Hemiptera, or an average of 1814, per acre. Of these,

Leptocoris trivittatus was the most numerous. *Euschistus variolarius* and *Eurygaster alternatus*, although not quite so plentiful, were more generally distributed. Their numbers were 61, 56, and 59, respectively.

The injurious insects totaled 4,419 per acre and beneficial forms totaled 1,289 per acre. Of the total, 76 per cent were injurious, 22 per cent were beneficial, and 2 per cent were of unknown economic importance.

The arrangement of the insects into three groups—beneficial, injurious, and unknown—is somewhat arbitrary. The status of some of these insects may be changed when their habits become better known.

Gryllus assimilis, Agallia californica, Eurygaster alternatus, Leptocoris trivittatus, Neides muticus, Anasa tristis, Diabrotica soror, and *Cycloneda munda* were determined by the junior writer. The caterpillars, noctuid larvae, carabid larvae, Chrysopa larvae, pentatomid nymphs, mirid nymph, locustid nymph, 1 cydnid, 2 staphylinids, and 11 ants listed were lost or destroyed before they could be determined. The other species were kindly identified by the specialists of the Bureau of Entomology as listed below.

INSECTS FOUND ON PEA FIELDS AFTER HARVEST

Beneficial

Hemiptera:

2 *Geocoris atricolor* Montd. (Lygaeidae).
17 *Nabis ferus* (L.) (Nabidae).
17 *Nabis major* Costa.
Determined by H. G. Barber.
2 *Neides muticus* (Say). (Neididae).
Determined by F. G. Hinman.

Coleoptera:

2 *Calosoma tepidum* Lec. (Carabidae).
1 *Notiophilus nitens* Lec. (Carabidae).
1 *Anisodactylus semipunctatus* Lec. (Carabidae).
3 *Sericoda* near *variolata* Lec. (Carabidae).
2 *Celia sp.* (Carabidae).
2 *Amara hesperia* Csy. (Carabidae).
18 *Amara lacustrina* Csy. (Carabidae).
5 *Amara sp.* (Carabidae).
Determined by L. L. Buchanan.
1 Carabidae larva.
4 *Dermestes medialis* Csy. (Dermestidae).
27 *Collops versatilis* Fall (Melyridae).
Determined by H. S. Barber.
67 *Hippodamia convergens* Guér. (Coccinellidae).

5 *Hippodamia parenthesis* (Say) (Coccinellidae).
3 *Hippodamia spuria* Lec. (Coccinellidae).
17 *Coccinella hieroglyphica humboldtiensis* Nun. (Coccinellidae).
1 *Coccinella novemnotata oregona* Csy. (Coccinellidae).
2 *Scymnus marginicollis* Mann. (Coccinellidae).
Determined by E. A. Chapin.
2 *Cycloneda munda* (Say) (Coccinellidae).
Determined by F. G. Hinman.
6 Coccinellidae. Undetermined.
5 *Staphylinus nigrellus* Horn (Staphylinidae).
9 *Quedius spp.* (Staphylinidae).
1 *Stenus sp.* (Staphylinidae).
4 *Tachyporus* near *chrysomelinus* L. (Staphylinidae).
Determined by E. A. Chapin.
2 Staphylinidae (destroyed).

Neuroptera:

1 *Chrysopa sp.* larva.

Hymenoptera:

1 *Platylabus sp.* near *tibialis* Ashm. (Ichneumonidae).
Determined by R. A. Cushman.
1 *Gonatopus sp.* (Dryinidae).
Determined by C. F. W. Meusebeck.

INJURIOUS

Orthoptera:

2 *Melanoplus femur-rubrum* Scudd. (Locustidae).
1 *Melanoplus saltator* DeG. (Locustidae).
Determined by A. N. Caudell.
2 Locustidae nymphs.
6 *Gryllus assimilis* (Fab.) (Gryllidae).
Determined by F. G. Hinman.

Homoptera:

16 *Acucephalus albifrons* (L.) (Cicadellidae).
Determined by P. W. Oman.
1 *Agallia californica* Bak. (Cicadellidae).
Determined by F. G. Hinman.

Hemiptera:

59 *Eurygaster alternatus* (Say) (Scutelleridae).
Determined by F. G. Hinman.
4 *Peribalus limbolarius* Stal (Pentatomidae).
24 *Chlorochroa congrua* Uhl. (Pentatomidae).
56 *Euschistus variolarius* (P. B.) (Pentatomidae).
2 *Thyanta custator* (Fab.) (Pentatomidae).
23 Pentatomidae nymphs.
1 Cydnidae (lost).

1 *Thyreocoris pulicarius* (Germ.) (Cydnidae).
2 *Ceraleptus pacificus* Barb. (Coreidae).
5 *Coriomeris humilis* (Uhl.) (Coreidae).
3 *Corizus scutatus* (Stal.) (Coreidae).
1 *Corizus indentatus* Hambl. (Coreidae).
Determined by H. G. Barber.
1 *Anasa tristis* (DeG.) (Coreidae).
61 *Leptocoris trivittatus* (Say) (Coreidae).
Determined by F. G. Hinman.
7 *Lygaeus kalmii* Stal. (Lygaeidae).
2 *Peritrechus tristis* VanD. (Lygaeidae).
1 *Peritrechus sp.* (Lygaeidae).
9 *Sphragisticus nebulosus* (Fall). (Lygaeidae).
1 *Crophius bohemani* (Stal) (Lygaeidae).
4 *Lygus pratensis* (L.) (Miridae).
Determined by H. G. Barber.
1 Miridae nymph.

Coleoptera:

324 *Diabrotica soror* Lec. (Chrysomelidae).
Determined by F. G. Hinman.
94 *Blapstinus gregalis* Csy. (Tenebrionidae).
Determined by E. A. Chapin.
1 *Melanotus oregonensis* (Lec.) (Elateridae).
Determined by W. S. Fisher.
47 *Sitona hispidula* (Fab.) (Curculionidae).
1 *Dyslobus decoratus* (Lec.) (Curculionidae).
1 *Dyslobus sp.* (Curculionidae).
Determined by L. L. Buchanan.

Lepidoptera:

4 Caterpillars.
3 Noctuidae larvae.

Hymenoptera:

2 *Aphaenogaster subterranea occidentalis* Em. (Formicidae).
8 *Formica fusca* L. var. (Formicidae).
Determined by W. M. Mann.
11 Formicidae. Not determined.

Economic Importance Unknown

Hemiptera:

12 *Alydus pluto* Uhl. (Coreidae).
2 *Tollius curtulus* Stal (Coreidae).
3 *Rhyparochromus chiragra* Fab. var. *californicus* VanD. (Lygaeidae).
1 *Emblethis vicarius* Horv. (Lygaeidae).
1 *Lyctocoris campestris* (Fab.) (Anthocoridae).
Determined by H. G. Barber.

Coleoptera:

1 *Anthicus floralis* (L.) (Anthicidae).

2 *Anthicus punctulatus* Lec. (Anthicidae).

Determined by H. G. Barber.

Hymenoptera:

1 *Pseudomethoca canadensis* (Blake). (Mutillidae).

Determined by G. A. Sandhouse.

2 *Cleptes sp.* (Chrysididae).

Determined by Sandhouse and Gahan.

From the same 78 plats all the peas remaining on the ground were collected. These peas were counted and 200 from each lot were dissected in order to find the number and percentage of pea weevils contained. From the data thus obtained the number of weevils per plat and per acre were estimated. The numbers of pea weevils ranged from a minimum of 6,534 to a maximum of 1,580,356 per acre. On the 78 plats the average number per acre was 307,098.

If the pea stubble were burned immediately after harvest, practically all of the remaining pea weevils would be killed. Each day that burning is put off increases the number which emerge from the peas and escape, as well as the number of other injurious insects which migrate from the fields and escape destruction. In sections where gardens are growing near pea fields, the burning of the pea stubble may prevent the destruction of the gardens by the insects which would migrate from the pea field.

INJURY AND DISTRIBUTION OF POTATO FLEA-BEETLE IN WASHINGTON

Epitrix cucumeris Harris, *Epitrix subcrinita* Leconte

By R. L. Webster, *Washington Experiment Station, Pullman, Wash.*

Abstract

Severe injury to potato tubers occurs in western Washington, in areas where *Epitrix cucumeris* is the predominant species. The western potato flea beetle *Epitrix subcrinita* is common in eastern as well as in western Washington.

Counts of more than 40,000 beetles indicate that the relative abundance of the two species varies greatly in different areas. *Epitrix cucumeris* appears to be extending its distribution in western Washington from Grays Harbor and Pacific counties as a center. This species has not been collected from eastern Washington.

Injury by flea-beetles to potato tubers has resulted in considerable loss in western Washington during the past six years. While the greatest injury is that caused by the larvae to the tubers, damage to foliage often is severe. In those areas where severe injury to tubers occurs, the pre-

dominant species is *Epitrix cucumeris*, the potato flea-beetle of the eastern states. Where this species does not occur in the state, damage to potato tubers is of little or no consequence.

In eastern Washington, only one species of flea-beetle has been collected from potato fields: *Epitrix subcrinita*. The same species occurs all over western Washington, but *Epitrix subcrinita* is not known in the eastern United States. Our studies indicate that the larvae of this western species of flea-beetle feed mostly on the roots of the potato plant, rather than on the tubers. Larvae dug from about the roots at Puyallup, several inches distant from the nearest tubers, indicate that such may be the case. On the other hand, the injury observed on tubers at Mt. Vernon, where *Epitrix cucumeris* has not been collected, is evidence that this western species may cause tuber injury as well as root injury.

These two kinds of flea-beetles are very similar in general appearance and have often been confused, even in museum collections. In practice, however, it is not difficult to separate the two when a large number are examined with the aid of a hand lens. The western species is the larger of the two and nearly always has a decided bronze or brassy appearance. The eastern species usually is jet black in appearance, both above and below, although specimens collected in Iowa by the writer have antennae and legs of a lighter color. This color characteristic, together with the slighty smaller size, is usually sufficient to distinguish this species from its close relative, our native western species.

Counts of more than 40,000 of these beetles, collected by sweeping with an insect net in fields where injury has occurred at various times during the summer months, indicate that the small black beetle is by far the more abundant of the two in the area of severe infestation in western Washington. The data on which these counts are based represent collections by Wm. W. Baker, J. F. Gates Clarke, and the writer.

Area Where Damage Occurs. From Grays Harbor County as a center, where injury was severe as early as 1925, damage by the flea-beetle appears to have slowly expanded in area over western Washington. In Mason County potato growers first reported the flea-beetle as a pest in a few sections in 1926. The area affected in that county by the insect gradually increased in extent each year for the next three years, and by 1929 the insect was serious over the entire county.

In this area, according to counts of over 21,000 insects, the western flea-beetle was outnumbered by *Epitrix cucumeris* by 5 to 1. The actual counts follow:

	Locality	Date	*E. subcrinita*	*E. cucumeris*
Area No. 1.....	Raymond	Aug. 7, 1929	56	1,678
Pacific and	South Bend	Aug. 23, 1929	155	430
Grays Harbor	Longbeach	June 24, 1930	2	12
counties.....	Oysterville	Aug. 23, 1929	0	337
	Rochester	Aug. 6, 1928	20	76
	Oakville	July 6, 1929	96	132
	Fords Prairie	Sept. 1, 1929	188	1,105
	Elma	July 25, 1928	42	275
		July 27, 1927	812	16
		Sept. 6, 1927	78	461
		Sept. 13, 1927	150	765
	Brady	July 5, 1929	32	391
	Montesano	June 22, 1929	2	66
		July 4, 1929	34	413
		July 5, 1929	18	293
		July 6, 1929	9	61
		July 15, 1929	23	176
		July 22, 1930	86	399
		July 23, 1930	68	394
		July 25, 1928	34	315
		Aug. 4, 1929	0	144
		Aug. 9, 1928	17	1,158
		Aug. 9, 1929	49	601
		Aug. 10, 1929	111	763
		Aug. 18, 1927	167	317
		Sept. 2, 1929	74	2,514
		Sept. 14, 1929	982	3,043
		Sept. 17, 1927	20	499
	Wynoochee	Sept. 3, 1927	36	449
		Sept. 14, 1927	115	343
	Aberdeen Gardens	June 26, 1930	2	104
	Burrows	July 17, 1929	63	77
		Aug. 8, 1929	34	434
Total.....			3,575	18,241

In Lewis and Cowlitz counties potato growers complained of flea-beetles first in 1925. Numerous potato fields in the vicinity of Monroe and Randle in Lewis County were severely injured in August, 1929. In Lewis County *Epitrix subcrinita* was outnumbered by *cucumeris* by more than 18 to 1.

Locality		Date	*E. subcrinita*	*E. cucumeris*
Area No. 2.....	Chehalis	June 30, 1929	60	312
		July 29, 1928	102	223
Lewis County...		Aug. 6, 1929	69	584
	Elbe	Aug. 17, 1929	7	190
	Morton	Aug. 5, 1929	73	4,432
		Aug. 17, 1929	3	369
	Randle	Aug. 6, 1929	75	1,084
Total.....			389	7,194

Scattered reports of injury have come in from Clarke County, where potatoes in the vicinity of Amboy, Battleground, and Washougal have been affected. Injury at the last-named location was first reported in

1921, and a single report of injury from Vancouver dates back to 1914. Robert Cowan, formerly county agent in Grays Harbor County, reports having observed injured tubers from practically all counties west of the Cascade Mountains at the Spokane Potato Show in 1927.

In this section of the state there is less difference in the relative abundance of the species, although the western species is rather more common than the eastern *cucumeris*.

Locality		Date	*E. subcrinita*	*E. cucumeris*
Area No. 3	Vancouver	June 29, 1929	408	3
	Battleground	Aug. 8, 1930	154	27
Cowlitz and	Ridgefield	Aug. 23, 1930	296	231
Clarke counties	Castle Rock	July 28, 1928	71	299
		Aug. 15, 1928	391	371
		Aug. 17, 1928	1	92
Total			1,321	1,023

Flea-beetle injury was first observed in Thurston County in 1925, and by 1928 the insect was serious over practically the whole county. In Pierce County in the vicinity of Elbe there was no noticeable flea-beetle injury in 1926. In 1928 the crop in that vicinity was disqualified for certification by the State Department of Agriculture because of tuber injury.

Counts made in this area indicate that the native western flea-beetle outnumbers the eastern *cucumeris* by more than 4 to 1.

Locality		Date	*E. subcrinita*	*E. cucumeris*
Area No. 4	Olympia	July 28, 1927	25	89
Thurston and	Olympia	Aug. 10, 1929	197	185
Pierce counties	Fox Island	July 2, 1929	35	5
	Puyallup	July 1, 1929	88	9
	Puyallup	July 12, 1927	94	0
	Puyallup	Aug. 1, 1927	146	0
	Puyallup	Aug. 29, 1929	241	102
	Puyallup	Sept. 1, 1927	379	1
	Puyallup	Sept. 23, 1927	454	0
Total			1,659	391

In 1931 tuber injury was observed in the vicinity of Puyallup and also at Mount Vernon, although such injury had not previously been recognized in those localities. Since the flea-beetle punctures did not number over five or six to a large tuber, the damage was considered as slight. Collections in Skagit and Whatcom counties indicate that only the western species is present. No clearly recognizable specimens of *cucumeris* were found.

Locality		Date	*E. subcrinita*	*E. cucumeris*
Area No. 5	Mt. Vernon	July 19, 1928	135	0
	Samish Lake	Aug. 17, 1930	169	0
Skagit and	Bellingham	July 23, 1928	32	0
Whatcom	Bellingham	Aug. 18, 1930	2,016	0
counties	Ferndale	Aug. 18, 1928	26	0
Total			2,378	0

Damage to tubers in eastern Washington was reported from Yakima for the first time in 1931. Recently Charles D. Gaines, in charge of certification work for the State Department of Agriculture, reported slight injury to Yakima-grown potatoes. Until this time potatoes grown in the Yakima Valley had been free from tuber damage. In Kittitas County and in Palouse country potatoes seem to be practically free from injury. Our records show that damage to foliage is rare in Kittitas County and also in the Yakima Valley. On the other hand, injury to foliage by the beetles, in this case *Epitrix subcrinita*, has been common in the vicinity of Walla Walla, and in Whitman and Spokane counties. Yothers reported severe damage to potato foliage which took place during the summer of 1913 in eastern Washington.

In eastern Washington again no specimens of *E. cucumeris* were collected. Several very dark specimens were observed at one time or another, but without exception these were slightly bronze in appearance and were classed as *Epitrix subcrinita*.

Locality		Date	*E. subcrinita*	*E. cucumeris*
Area No. 6	Ellensburg	Aug. 15, 1930	63	0
	Yakima	July 17, 1928	27	0
Eastern Wash-	Prosser	July 16, 1928	103	0
ington	Walla Walla	Aug. 13, 1930	1,738	0
	Pullman	Aug. 19, 1928	235	0
	Pullman	Aug. 5, 1930	956	0
	Pullman	Aug. 7, 1930	1,152	0
	Palouse	Aug. 21, 1929	446	0
	Spokane	Aug. 26, 1929	49	0
	Couer d'Alene, Ida.	Aug. 3, 1930	422	0
Total			5,191	0

THE USE OF *TRICHOGRAMMA MINUTUM* (HYMENOPTERA CHALCIDIDAE) RILEY IN THE CONTROL OF THE CODLING MOTH IN COLORADO

By GEO. M. LIST, and L. G. DAVIS

ABSTRACT

Mention is made of the beneficial effect on Trichogramma by feeding.

Mass liberations and colonization liberations were tried. The results varied in different orchards with both methods. During years of high natural parasitism the liberations show little benefit. The benefit of liberations during years of low natural parasitism is of doubtful value as indicated by fruit counts.

The laboratory end of the Trichogramma work has been discussed by a number of writers and is now quite well standardized so this paper will only touch upon this phase. Our effort has been to produce the parasite in only such numbers as were needed for limited orchard liberations. In this we have had to overcome our natural low humidity and solve several pest problems that developed in the handling of the host moth breeding units. These problems have been best met by producing the Angoumois grain moths in units that hold about 400 pounds of grain, and infest these heavily, with the idea of getting the maximum production in a short period. Large kernel soft wheat has proven superior to other grains. The length of life, vigor, and prolificacy of Trichogramma have been greatly increased by certain feeding methods. Water alone is beneficial but difficult to supply without many parasites drowning. Honey and various sweetened liquids are good but subject to the same criticism. The most convenient and satisfactory food is the raisin. When these are exposed in an air having a relative humidity of around 70 per cent they become soft and slightly sticky. When in this condition the Trichogramma work over them and very evidently take food, with the result that the average length of life, which with us has been only about 3 days, is more than doubled. The uncertainty of an increase, that bothered so much during the early part of the work, has not been experienced for more than a year and the adults have been much more active. It is possible that adults liberated in the orchards may find some natural supply of food and moisture but if they do not there are great possibilities of increasing their effectiveness by feeding before liberations are made. This is being tried at the present time; but it is too early to determine its value.

Two general plans of liberation have been followed. First: that of mass liberation or "flooding," with the idea in mind of having parasites

present in sufficient numbers at all times to destroy the codling moth eggs as they are deposited. Little consideration has been given to the value of the increasing orchard population. In other words, it has been an attempt to determine if the Trichogramma under Colorado conditions can effect a control when they are kept constantly present in the trees in reasonable numbers. The second method has been that of colonization. Single or infrequent liberations of varying numbers have been made at different times of the season, with the hope that the parasite would become established and increase sufficiently to be of value.

Liberations have for the most part been made by placing cards of parasitized grain moth eggs in the trees in tarlatin bags, capsules or other devices that gave protection against predators and allowed the parasites to escape. All liberations reported on here were made in the Grand Junction section where the codling moth population is unusually high.

No entirely satisfactory method of checking upon the results has been found. It is very difficult to get a true picture of the actual parasitism taking place during a given period of the season. This is the information that should be available but for the most part we have had to be content with counts that represented the accumulated parasitism for the season prior to the date of observation. All percentages herein given are of that nature. Due to natural occurrence of the parasite in the orchards a single check orchard has not been considered the best, so observations have usually been made in several.

This natural parasitism has varied more from season to season than between orchards. For instance, it was very high and quite uniform during 1930, but uniformly low or almost absent during 1931.

About one and a half million parasites were used in 1930 and two million in 1931. The 1930 liberations showed definite results in all orchards before natural parasitism was noted in check orchards, but after July 1 the natural parasitism increased to a point where it masked all effects of those liberated. If our liberations had been more general, it would have been a wonderful opportunity to claim all the results as due to the liberations.

The following records on a few representative orchards in which liberations were made in 1931 will give an idea of the results of that season. The natural parasitism throughout the fruit section was very low. In fact, it was impossible to find parasitized eggs in many orchards so practically all of the parasitism recorded can be attributed to the liberations.

INGRAHAM ORCHARD. The codling moth infestation in this orchard was probably below normal for the entire season. The regular arsenate of lead spray schedule was followed by the owner and parasite liberations were made on a limited number of trees in the center of the orchard regularly throughout the season, with the idea of having sufficient parasites present to effect a control. The first liberations were made May 29th and the first and only parasitized egg was taken the 28th day of July. We are unable to explain why the parasites were unable to colonize in this orchard. This is more puzzling in view of the fact that very encouraging results were secured in other orchards.

MYERS ORCHARD. The codling moth infestation in this orchard was known to be very heavy. The owner followed the regular codling moth spray program but probably did not do as efficient work as many growers. Ten trees were selected in the center of the 8 acre block and 10,000 parasites were placed on these every other day throughout the season. The first liberations were made May 29th. The first parasitized eggs were found June 16. From this time they increased quite rapidly. The following percentages, which are based upon rather extensive counts of eggs, will give an idea of the parasitism occurring:

July 2—Parasitized 25.25%.
July 22—Parasitized 90.83%.
July 28—Parasitized 85.3%.

At the end of the season, parasitized 70.27%. Hatched and unparasitized 28.72%. This would indicate that the highest activity of the parasites occurred during July. Other observations in the orchard bear out this conclusion.

An idea of the infestation that occurred in this orchard is indicated by the fact that one worker in 30 minutes was able to count 240 parasitized eggs, and by the fact that in spite of the high parasitism and the regular spray program being followed only 15% of the fruit was free from worm injury at the end of the season. Counts made at different distances from the trees where liberations were made, showed that there was a very marked spread of the parasites from this center. It extended throughout the 8 acre block with some decrease as we reached the farther trees.

KAPAUN ORCHARD. This was a 22 acre orchard that was unsprayed throughout the season. Regular liberations were made every other day on a number of trees near the center of the block. The first parasitized eggs were noted July 2. A count of eggs made on the fruit and leaves

at the end of the season showed a parasitism of 46.26%. This, however, was not sufficient to afford any protection to the fruit as the crop was a total loss on account of codling moth injury.

MURDOCK ORCHARD. This orchard was used as a test for the colonization of the parasites through a single liberation. The parasites were liberated from capsule containers. One tree received 5000 parasites; 1—2500; 4—1000 each; 4—500 each; 10—200 each and 35—100 each. We were unable to recover a parasitized egg on any of these trees.

HARTZLER ORCHARD. On July 13, 5000 parasites were liberated on each of 3 trees and 1000 on each of 25 trees. There was practically no difference in parasitism on the trees receiving different numbers. A small count made July 28 showed 34 eggs parasitized and 15 unparasitized. A more extensive count at the end of the season showed 40.56% of the eggs to have been parasitized and 59.43% unparasitized.

HARVEY ORCHARD. On July 13, 500 parasites were liberated on each of 20 trees. The spread of the parasites from this one liberation was as great, or even greater, than in orchards where many more were liberated. A count made at the end of the season showed a parasitism of 57.4% and a very pronounced spread occurred. The remaining codling moth population was sufficient to destroy the crop of fruit.

Some liberations were made in a number of other orchards, but these examples are representative. They indicate that during seasons of high natural parasitism little is accomplished by either mass liberations or by colonization of Trichogramma. During seasons of low natural parasitism liberations can be responsible for a pronounced parasitism but in no case has this been sufficient to show a marked control of the codling moth as indicated by fruit examinations. The mass liberation shows a considerable increase of parasitism over the colonization plan, but probably not enough to warrant the additional expenditure of time of liberation and cost of parasites. It is felt that a modification of the two plans giving liberations about 6 or 8 days, should be more practical. The writers feel that the results are encouraging enough to justify continuing the experiment but believe the growers should not be led to expect too much from it. The true value can be determined only by long series of control experiments.

There needs to be a careful study of Trichogramma from several angles. There are several strains that behave quite differently in the laboratory and probably are just as distinct in the orchard. A careful study of all the orchard hosts could well be made. Under Colorado conditions the parasite continues to breed later than the codling moth.

with the result that it must seek other host eggs. The presence of suitable later host eggs may therefore be as important as climatic factors in determining the overwintering Trichogramma population. The controlling of this by cultural or cover crop methods may give more pronounced results than the rearing and liberations.

NOTES ON THE BIOLOGY OF THE PEAR LEAF BLISTER MITE IN THE WEST

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ABSTRACT

The older ideas of the behavior of the blister mite (*Eriophyes pyri*) in the spring are not in accordance with their actual habits in the West. Several writers have suggested this; and the present writers have found that wintering mites deposit eggs in the buds, that blisters are made by the feeding of the generation coming from these eggs, that the mites do not enter the blisters until they are adult, and that this does not occur until the foliage is well out. Sprays applied after the buds have begun to open are apparently effective.

Most of the older works on economic entomology include statements regarding the biology of the pear leaf blister mite (*Eriophyes pyri* Pgst.) that do not seem to be capable of corroboration on the Pacific Coast. This may be due to lack of good microscopes in the earlier days, or it may be due to the existence of a different species or race in the West, or to a change of habits. Since a great deal of dormant nursery stock has been shipped from the East in the past, it seems impossible that the eastern *pyri* was not brought along with it; but we have, in the Pacific Northwest at least, a form that is apparently indigenous on the wild snowberry (*Symphoricarpos racemosus*), and that attacks the cultivated apple, but apparently not the pear. This was brought out by Childs in 1925.[1]

The habits that will be referred to in this paper are those of the mite from the time of hibernation until the fruit is set. It seems to be rather generally agreed in the East that the adult mites, which have wintered under the bud scales, burrow into the unfolding leaves from the under sides, that their feeding within the leaves causes the blisters, and that eggs are laid within the blisters. The mites are said to burrow into the leaves very early, so that lime-sulphur sprays must be applied while the trees are still dormant if they are to be effective.

[1]Childs, L. Oreg. Agr. Expt. Sta. Circ. 59, 1925.

In the West, the spring development of the mites does not take exactly the course just outlined. Weldon, in 1915,[2] mentioned finding eggs under the bud scales early in March in California, and stated that "apparently these eggs were hatching and mites of various sizes were seen." He surmised that damage to the foliage was caused by mites hatching from these eggs, and not directly by the wintering mites. Childs (loc. cit., p. 5) observed the same thing, stating that "no over-wintering mites were found established in the new developing leaves," and Urbahns, in 1927,[3] also noted the development of a generation of mites in the buds early in the spring.

On account of these published observations and because it has been known for some time in the West that a so-called "bud mite" occurs elsewhere than in blisters during most of the year, we have started an investigation of the habits of this pest at Yakima, Wash. We are publishing this preliminary note in the hope that observations will be made by others, especially east of the Rocky Mountains, that may help to explain why there is an apparent difference in habits in the two parts of the United States.

The first observations were made March 21, at which time the pear buds were just beginning to swell. There were large numbers of adult mites under the bud scales in many trees. Near the outer edges of the buds, and sometimes exposed, were numbers of dead mites. Other observers have mentioned finding cast skins, but a careful examination of these with a compound microscope showed that they were too thick and opaque to be exuviae. A few newly deposited eggs were found on March 21, and several days later they were very numerous, hundreds of them being found in a single bud. By April 2, most of the adult mites had disappeared and the eggs were beginning to hatch. Hatching continued for 10 or 12 days, and the earliest mites to hatch were full-grown by that time.

The first blisters were found April 15, at which time the earliest blossoms were open. Previous to that, mites had been observed feeding on the surface of the unfolding leaves, at times apparently with their heads buried in the tissue, but no mites had been seen actually to burrow into the leaf. Many small blisters were found that contained no mites and that did not even show the characteristic small opening on the ventral

[2]Mo. Bul. Cal. State Comm. Hort., IV, p. 219, 1915.

[3]Urbahns, T. D. The Pear Leaf Blister Mite. Mo. Bul., Cal. Dept. Agric., XVI, pp. 77–80, 1927.

side. These were found chiefly on fruit stems and petals. Mites were observed burrowing into blisters, and running in and out through the openings thus formed. These observations indicate that the blisters result from the irritation caused by the external feeding of the mites on the lower surfaces of the leaves, and that the mites then burrow into the blisters. This conclusion, however, must be corroborated by further observation before it can be accepted as definite.

Evidently only the adult mites of the first spring generation enter the blisters. Eggs were found within these blisters immediately, and a few were hatching several days later. As the mites run in and out of the blisters, it can not be said how many inhabit a single blister, but 5 mites and 40 eggs were found at one time in a blister shortly after the blisters were first formed. Many mites were still living on the lower surfaces of the leaves, and between the leaf stems, at that time, although the blossoms had opened and the leaves were well formed. During the following month, that is, until late in May, the number of mites in the blisters increased, chiefly from the development of a new generation. The blisters increased somewhat in size and became brown in color and filled with a dry, spongy material through which the mites burrowed.

About the first of June, new blisters began to appear on the young unfolding leaves of the new growth. An examination of this new growth showed many mites between the leaves that were still rolled up and in the pubescence on the lower surfaces of those that were opening. Apparently blisters form on the leaves only before they have completely unfolded.

These habits may have a bearing on the efficacy of control measures. It has been supposed that only a late fall or an early spring application of lime-sulphur solution was effective, because the mites were supposed to burrow into the newly developing leaves before the buds had opened. It is quite evident that this does not happen in the Pacific Northwest, no mites being found within the leaves until about a week before full bloom. An orchard was examined that was sprayed with lime-sulphur on April 8, at which time the bud clusters were open but the individual buds within had not separated. This was just a week before the first blisters were found in adjoining trees. No live mites could be found in the sprayed trees, although they had been numerous before the trees were sprayed. Supplementing this, it may be said that a great deal of dormant spraying has been done in the Pacific Northwest after the buds were well open, and that apparent control of the mites has been obtained if lime-sulphur was used.

On May 5, infested trees were sprayed experimentally with dormant-strength lime sulphur. Considerable damage was done to the foliage, but observations made three weeks later showed very few live mites on the sprayed trees as compared with those not sprayed. A considerable mortality had resulted, either on account of the mites' habit of running in and out of the blisters or because the sulphur fumes actually enter the blisters. However, the mortality was not complete and much damage had been done by the mites before the spray was applied. Therefore, a late application can not be recommended, even though there were no injury from the spray itself.

In summarizing these observations, it may be said that in the West the wintering adult mites deposit eggs in the buds and die. The young hatching from these eggs develop in the buds, and as they mature, their external feeding on the lower surfaces of the leaves apparently causes blisters to form. The adult mites of the first spring generation burrow intc these blisters and deposit eggs within them, and subsequent generations apparently develop within the blisters. New blisters began to appear on the young leaves about June 1, and there are always considerable numbers of mites feeding externally. Lime-sulphur sprays applied as late as the "cluster bud" stage of the pear buds appear to be effective.

EXPERIMENTS WITH TOXIC SUBSTANCES IN HIGHLY-REFINED SPRAY OILS

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Soon after highly-refined spray oils came into use the fact became evident that oils of this type are not particularly toxic to insects. Investigations made by de Ong, Knight and Chamberlin[1] during 1924 and 1925 indicated that lethal action is due to suffocation brought about by the oil penetrating and blocking the tracheae. The commercial use of the oils in the control of the California red scale, *Chrysomphalus aurantii* (Mask.), on citrus trees revealed that they are far less effective than at first believed. In order to obtain a percentage-kill high enough to give a satisfactory degree of control where large numbers of insects are present, it is necessary to use oils which are so heavy, or to use such a high percentage of oil in the spray, that markedly deleterious effects

[1]E. R. de Ong, Hugh Knight, J. C. Chamberlin. A preliminary study of petroleum oil as an insecticide for citrus trees. Hilgardia 2: 351–384, January, 1927.

often result to the trees. When the writer took up the investigation of oil sprays in 1926, the most promising line of research was that of attempting to increase the effectiveness of the oils by incorporating toxic substances in them. The research of 1926, 1927, and 1928 was devoted largely to experiments with toxicants and the study has been continued as a minor project up to the present time. A brief report was published in 1929.[2]

The larger part of the research has involved laboratory experiments with lemons infested with the California red scale. Lemons bearing from 50 to 300 or 400 insects each are brought into the laboratory and sprayed in a manner that insures a complete coverage of all insects. The sprayed fruit is placed in paper bags and set aside for three weeks, and then counts are made to determine the percentage of insects surviving. This method is very satisfactory since the insects readily thrive on ripe lemons providing the fruit is not allowed to dry up. Kerosene and mineral seal types of oils chiefly are used as carriers for the substances tested. The oils have ranged from 32 to 55 seconds viscosity (Saybolt at 100° F.) and from 95 to 98 per cent unsulfonated residue. The spray is applied in the form of a mechanical mixture of oil and water. The results obtained in the laboratory have been checked by orchard tests, using light-medium and medium spray oils as carriers for the toxicants.

Among the substances of particular interest which have been tested are nicotine, pyrethrin, rotenone, pyridine, furfurol, paradichlorobenzene, orthodichlorobenzene, carbon tetrachloride, carbon disulfide, ethylene dichloride, 3–5 dinitro-o-cresol, hydrocyanic acid; various extracts of pyrethrum, *Derris elliptica*, *Tephrosia* sp., *Lonchocarpus* sp., and "Haiari," various organic compounds of cyanide, arsenic, mercury, sulfur, and selenium. Various intermediate solvents have been employed to increase the solubility of the toxicants in the oils. Butanol is an effective intermediate solvent for 95 per cent nicotine and spray oils, and butyl phthalate increases the solubility of rotenone in the oils. However, the use of intermediate solvents does not accomplish the objective of making the toxicant permanently oil-soluble. For example, the use of 1 part of butanol, 5 parts of 95 per cent nicotine, and 94 parts of spray oil gives a clear solution, but when 2 parts of this solution are mixed with 98 parts of water in spraying, the nicotine readily passes from the oil to the water phase of the mixture. Since intermediate solvents

[2]Smith, Ralph H. Experiments with toxic substances in spray oils in controlling the red scale. California Citrograph 14: 315, 326, June, 1929.

may affect the oil-depositing quality of the spray and also may react chemically with the toxicant, control tests were made using the oil and toxicants without the intermediate solvents. Oil-soluble substances such as pyrethrin, which remain completely in the oil phase, would seem to afford much greater promise than those which are hydrophilic. During the past year tests were made with a product containing nearly 4 per cent actual pyrethrins.

The attempt to increase the effectiveness of spray oils by the use of toxicants, in the experiments with the California red scale, has been unsuccessful. The various substances have been tested at higher concentrations than would be economically practical for orchard treatments. This outcome is explained in part at least by the observation that with a large percentage of insects the oil does not reach the tracheae. In this case, if the insect succumbs, death is apparently caused by a prolonged impairment of physiological processes such as might be induced by the presence of the oil in the scale covering or in contact with the derm of the insect's body. By increasing the percentage of oil in the spray, beyond that which the trees normally will tolerate, sufficient oil may be deposited so that it reaches the spiracles and killing may then be caused more directly by the presence of oil in the tracheae. In this case, the findings indicate that death with toxic oils is quicker, but apparently no more certain to occur, than with the highly-refined oil alone.

The Sicilian Mealybug Parasite in Illinois. Specimens of an encyrtid parasite, reared by C. C. Compton from the Mexican Mealybug, *Phenacoccus gossypii* (T. & Ckl.), in the University greenhouse at Urbana, Ill., April 29, 1932, have been identified by the writer as *Leptomastidea abnormis* (Girault). This parasite was introduced from the Mediterranean region into California in 1914 and established to combat the Citrus Mealybug, *Pseudococcus citri*. From there it was sent to Florida in 1917. Its appearance in Illinois in abundant numbers and attacking the Mexican Mealybug seems rather surprising. *Phenacoccus gossypii* was first observed in Illinois in a greenhouse in 1928 and since that time has become one of the most serious of greenhouse pests. It would appear to be a comparatively easy matter to widely distribute and utilize this beneficial parasite in checking the work of both species of mealybugs wherever they are present under glass.

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SOME REMARKS ON THE PHYSIOLOGICAL ACTION OF OIL SPRAYS[1]

By A. L. STRAND, *Montana Agricultural Expt. Station*

ABSTRACT

A discussion of the probable trend in this type of physiological work with emphasis on the study of the oxidation-reduction systems in plant and animal tissue.

The great forward march in the use of oil sprays has been due to practical field tests and not in any great extent to laboratory accomplishments. Yothers, Ackerman, Spuler (to mention only three) and the work which their names recall will cause this assertion to be granted, I believe. In fact, the remarkable developments in oil sprays during the past ten years makes one wonder if the laboratory explanations which have followed up the findings based on field experiments have in the most part been very much worth while. It is probably true, however, that in the present stage of development in this important class of insecticides, the finer technique of the laboratory will begin to assume greater importance than would seem to accrue to it based on past accomplishments.

The number of papers dealing with the physiological action of oils, both relating to the insect and to the plant, especially the latter, is increasing. It is the main object of this present paper to consider where this work is leading.

On the plant side I can see several landmarks in the study of the physiological action of oil sprays. First, the work of Volck (1) published in 1903. He showed in connection with distillate sprays that the physiological effects were due to: (a) the purely physical blocking off of plant tissue, and (b) to what may be called the chemical action of certain toxic constituents in the oil. I have read a number of papers published a generation after Volck's California bulletin appeared which have only repeated his work but failed to give nearly so clear a statement of the problem as he set it down. The second landmark, in my estimation, was a paper entitled "California Petroleum Insecticides" by Gray and de Ong (2). Here, I believe, the relation between the percentage of unsulphonated residue and plant injury was first proposed and backed up by significant data. The last landmark includes the work of Knight, Chamberlain and Samuels (3). In this paper the penetration of the oils and the gross physiological action of them was well covered. As a teacher of economic entomology and as an experiment station investigator

[1]Contribution from Montana State College, Agricultural Experiment Station. Paper No. 21, Journal Series.

I would be happy if no more papers dealing with the effects of oil sprays on plants were published unless they contain something not to be found in the papers just mentioned.

On the insect side of the problem of the physiological action of oils, as with plants, there are two main divisions of the subject. First the consideration of those physical or physico-chemical factors which promote what may be called the availability of the oil—the physical phenomena which bring the oil in intimate contact with the insect. This subject, or the fundamental principles underlying it, have been well worked out by Cooper and Nuttall (4), Moore and Graham (5), and others. The importance of wetting and spreading has been emphasized again and again—but not measured. Recent work along this line has been based on some false assumptions or has been hitting around the same old mark, but coming no closer to it than the first early publications.

The second division has to do with the factors which we think in most instances actually cause the death of the insect. The total toxic action of an oil spray may be thought of as follows:

$$\text{Toxicity} = \text{physical action} \times \text{chemical action.}$$

In the purification of lubricating oils, by which the unsaturated components and no doubt some other materials are removed from the oil, its chemical action is decreased by successive purification and its physical effects emphasized. It is entirely probable that in some oils and against particular insects one of the above factors becomes so important as to entirely overshadow the other. However, at this point we wish to discuss the chemical action only. What I have to say about the direction this phase of the work is taking applies equally as well to this factor as involved in the physiological action of oil sprays on plants. We need to consider only those two Michigan Technical Bulletins, Nos. 11 and 21, published in 1911 and 1915. These, I am sure, are the most frequently cited references in insecticide work—the most frequently cited but the most infrequently read. I am convinced that this is the case for were it not so this journal would be lacking a number of titles which have been contributed to it. The work of George D. Shafer just referred to is, in my estimation, the most logical and exhaustive treatment of a research problem to be found in the literature of economic entomology. It is the only fundamental work which has been done on insect respiration in this country, although accorded no attention by recent writers who have endeavored to review that subject. It covers a wide field; in more than one instance current numbers of physiological journals are carrying articles which confirm Shafer's 1911 work without any reference to it.

We should be able to learn something from Shafer's work. We should be able to detect from it where similar problems are going to lead. He followed the possible toxic action of contact insecticides from the time they entered the tracheal system, or came in contact with the integument, to their action on the constituents of individual cells. We can on the whole draw certain conclusions from Shafer's development of his subject, that is, we can draw conclusions both from the findings which he discarded as being irrelevant to the final answer to the question and from those which he emphasized as being important. Some of these are:

(1) Histological technique will carry us just so far and there it leaves us—usually a long way from where we intended to go. It is true that Knight and his co-workers have increased our knowledge of oil sprays through such methods in that it was necessary to distinguish carefully between the physical and chemical effects. But the fact remains that many of the real happenings in which we are interested have taken place long before any change can be demonstrated through histological methods. In the words of Dr. Ellice McDonald, it is just as possible to reach our goal through such methods as it is to erect a bolt of lightning from the shattered tree which has been left behind.

(2) The measurement of carbon dioxide output alone is a snare and a delusion. Even the estimation of the complete respiratory quotient, while immeasurably better than only half of it, indicates only some stimulation or depression of the respiratory function. To be sure, such measurements constitute important symptoms and are useful in physiological work but should not be looked upon for a moment as complete explanations of what is actually taking place.

(3) The final answer to the problem is to be found in the study of the oxidation-reduction mechanisms in the cell. Shafer dealt only with the respiratory enzymes. They make up only a part of the several constituents of the cell concerned in these oxidation processes.

The question may be asked: why not go directly to this point in our problem and eliminate the intermediate steps which finally brought Shafer to it? There are several reasons for not doing so if one wishes to make out a case for that side. Here is where the work is leading, but one—particularly an entomologist—pauses to consider a few things. First of all he will realize that in the cell very probably is the most intricate mechanism that exists and, without any doubt whatsoever, the most important. This must be so; these oxidation-reduction systems in the cell are the essence of life itself. We can judge also from the

opinions of others. What appears to be but a small addition of new information to this subject is usually rewarded by the Nobel prize. Among the names of Bach, Hopkins, Warburg, Wieland, Thunberg, Keilin, you will find half of them in the Nobel list. I am calling attention to these names associated with the role in the cell of enzymes, glutathione, oxidation by dehydrogenation, cytochrome, etc., because Shafer has shown in the instance of one of these mechanisms that it is all important from the standpoint of the action of contact insecticides. We are justified in assuming that the others may be as much or even more concerned.

It is in relation to the effects which the constituents of oil sprays have on these cellular systems that real findings will be made, inconsistencies in toxic action ironed out, and the actual physiological effects established. That much, we believe, is clear. If so-called physiological work in connection with oil sprays cannot be directed at least in part toward this goal, let us forget this physiological flare and turn the entire matter over to biological chemists. That is probably where it belongs anyway. Let us not delude ourselves into believing that superficial attacks on the problem are going to yield important results.

On the other hand, if we are to pursue this line of work, let us follow in the footsteps of Shafer; he has led the way.

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WATER-SOLUBLE ARSENIC IN OIL EMULSION–LEAD ARSENATE COMBINATION SPRAYS[1]

By R. H. ROBINSON, *Chemist, Oregon Agricultural Experiment Station*

ABSTRACT

Laboratory studies of oil emulsion-lead arsenate combination sprays with distilled water as a diluent, reveal that excessive amounts of water-soluble arsenic are liberated by chemical reaction. When alkaline spray waters are used in preparing the mixture, the amount of water-soluble arsenic is increased materially and one water showed as high as 25% of the total arsenic of the lead arsenate had changed to the soluble form. In order to prevent as much as possible severe foliage injury, the use of hydrated lime is recommended to re-precipitate the soluble arsenic as basic calcium arsenic. A half pound of lime is suggested for each one hundred gallons of the combination spray.

During recent years there has been a very rapid growth in the use of summer oil sprays throughout the northwest fruit districts. These oil sprays are used principally for the control of red spider and as a supplement to lead arsenate in codling moth control. At least two applications of the oil emulsion-lead arsenate combination spray are recommended during the growing season in addition to several other cover sprays of lead arsenate alone. Members of the Western Cooperative Oil Project have reported foliage injury that varied from negligible amounts to partial defoliation of the tree that was attributed to the combination sprays.

It is quite generally recognized that water-soluble arsenic in comparatively small amounts will cause severe foliage injury under climatic conditions favorable to burn. Since certain combinations of the commercial products seem to produce more injury than others, the liberation by chemical action of excess soluble arsenic was indicated. Accordingly, a study was undertaken to learn to what extent water-soluble arsenic is formed in combination sprays of commercial oil emulsions and lead arsenate.

EXPERIMENTAL PROCEDURE. During the study of the reaction between oil emulsions and lead arsenate, an endeavor was made to simulate practical orchard conditions. Usually it takes one-half to one hour's time to apply a 300 gallon tank of spray. Consequently the amount of soluble arsenic that is formed in a laboratory mixture after one-half hour's agitation, would approximate the amount liberated in the tank of spray that is being applied in the orchard. In these studies the oil emulsion was used at the rate of one gallon to the hundred, and the lead ar-

[1]Published as Technical Paper No. 181 with the approval of the Director of the Oregon Agricultural Experiment Station.

senate was added at the rate of 4 pounds to the hundred gallons. The sequence of procedure was as follows: The concentrated oil emulsion was weighed out quickly to avoid loss of ammonia and a little distilled water added to a creamy consistency. It was then diluted with distilled water to spraying strength and the lead arsenate added. The mixture was then agitated in a mechanical shaking machine for one-half hour, one hour, and six-hour periods of time. Samples were then withdrawn, centrifuged immediately at about 3,000 r.p.m. for 5 minutes, and finally filtered through a Pasteur-Chamberlain filter. This gave a water-clear filtrate which was analyzed for its arsenic content.

In the following tables the different commercial lead arsenates are designated by letters and the oil emulsions by numbers. Brand names are omitted since different lots of one brand may vary appreciably in composition. The soluble arsenic is reported in milligrams per liter and also as percentage of the total arsenic oxide of the lead arsenate that changed to water-soluble form. The results obtained after shaking the mixture thirty minutes and one hour were so similar in most cases that the latter figures are omitted.

Table 1 reports the amounts of soluble arsenic formed when various commercial emulsions and lead arsenate A were combined. This arsenical contained originally only 2.4 mg. water soluble As_2O_5 per liter.

TABLE 1. WATER-SOLUBLE ARSENIC IN COMBINATION SPRAYS OF COMMERCIAL OIL EMULSIONS WITH LEAD ARSENATE A

Oil Emulsion No.	Soluble As_2O_5 after shaking		Percentage As_2O_5 soluble after	
	30 min. mg. per liter	6 hrs. mg. per liter	30 min. %	6 hrs. %
1	19	21	1.20	1.32
2	113	114	7.13	7.20
2a (old sample)	26	28	1.64	1.76
3	36	47	2.27	2.96
4	16	20	1.01	1.26
5	31	31	1.95	1.95
6	13	19	.82	1.20
7	83	110	5.24	6.95
8	47	52	2.96	3.28
9	82	106	5.16	6.68
10	88	97	5.55	6.12
11	116	130	7.32	8.20
12	42	49	2.64	3.09
13	57	66	3.59	4.16
14	44	82	2.77	5.16
15	27	29	1.70	1.83
16	15	23	.95	1.45
17	33	41	2.08	2.59
Lab. emulsion	13	19	.82	1.20

The results in Table 1 disclose some very remarkable data. Assuming that 16 mg. per liter, or more, water-soluble arsenic would cause foliage

injury, most of the combination probably would produce severe burning especially under conditions of high humidity and temperature. The small differences in results after shaking the mixtures thirty minutes and six hours indicate a rapid chemical change of the arsenic in the lead arsenate to the soluble form.

In the manufacture of oil emulsions the principal emulsifying agent used is casein. This is dissolved in an excess of ammonium hydroxide or other alkali. When excess ammonium hydroxide is employed to dissolve the casein, the chemical reaction with lead arsenate may be represented by the following equation:

$$5\ PbHAsO_4 + 6\ NH_4OH \longrightarrow Pb_5OH(AsO_4)_3 + 2(NH_4)_3AsO_4 + 5\ H_2O$$

The reaction therefore changes lead hydrogen arsenate to a basic arsenate with liberation of soluble ammonium arsenate.

A determination of the total alkalinity of the various emulsions showed that the amounts found were approximately proportional to the soluble arsenic produced after reaction with lead arsenate. Aeration of the emulsion removes excess ammonia and then very little soluble arsenic forms after mixing with the arsenical. In storage also ammonia is lost. This is apparent from emulsion No. 2A which was taken from a gallon can of emulsion No. 2 after six months' storage. Some of the emulsion contained other alkalies than ammonium hydroxide and also small amounts of potassium oleate. These ingredients account for increased soluble arsenic after six hours' shaking.

In order to observe the reaction of an oil emulsion on various commercial lead arsenates, brand No. 2 was combined with the several arsenicals and the soluble arsenic determined as before. Table 2 reports the results obtained.

TABLE 2. WATER-SOLUBLE ARSENIC IN COMBINATION SPRAYS OF COMMERCIAL LEAD ARSENATES WITH OIL EMULSION NO. 2

Lead Arsentae	Soluble As_2O_5 after shaking 30 min. mg. per liter	6 hrs. mg. per liter	Percentage As_2O_5 soluble after 30 min. %	6 hrs. %
A	113	114	7.13	7.20
B	103	103	6.50	6.50
C	94	112	5.93	7.07
D	57	66	3.59	4.17
E	23	93	1.45	5.86
F	92	104	5.80	6.57
G	79	94	5.00	5.92
H	54	66	3.41	4.16

It is apparent from the results in Table 2 that all commercial arsenates of lead do not react to the same extent with a strongly alkaline

oil emulsion. The presence of a deflocculent probably explains the lowest results obtained, but other factors must account for the smaller variations.

REACTION WITH ARSENATES CONTAINING DEFLOCCULENTS. Some commercial lead arsenates contain deflocculents incorporated in the hope of improving the product for certain specific purposes. To learn the influence of the deflocculent on the formation of water soluble arsenic, mixtures were made as outlined above. The results for a few typical emulsions, combined with two arsenicals that contained deflocculents, are given in Table 3.

TABLE 3. WATER-SOLUBLE ARSENIC IN COMBINATION SPRAYS OF OIL EMULSIONS AND LEAD ARSENATE CONTAINING DEFLOCCULENTS

Oil Emulsion No.	Soluble As_2O_5 after shaking 30 min. mg. per liter	6 hrs. mg. per liter	Percentage As_2O_5 soluble after 30 min. %	6 hrs. %
		Lead Arsenate B		
2	103	103	6.50	6.50
3	38	51	2.39	3.22
5	10	16	.63	1.01
6	5	5	.31	.31
8	43	43	2.71	2.71
11	79	101	4.98	6.37
		Lead Arsenate E		
2	42	97	2.65	6.12
3	23	41	1.45	2.59
5	7	14	.44	.88
6	4	7	.25	.44
8	28	40	1.76	2.52
11	33	85	2.08	5.36

It is very evident from the data in Table 3 that deflocculents in arsenicals retard the chemical reaction caused by alkaline emulsions. Judged by the smaller quantities of soluble arsenic found for arsenate E some types of deflocculents are more effective than others.

INCREASED SOLUBILITY EFFECT OF ALKALINE SPRAY WATERS. Most waters available in the orchard for spray purposes contain appreciable amounts of soluble salts, and furthermore may be very alkaline in reaction. Comparatively small amounts of chlorides and carbonates also will react rapidly with arsenate of lead, forming soluble arsenic. When such waters must be used for diluting oil emulsion-lead arsenate sprays, abnormally large amounts of arsenic may be brought into the soluble form. Since such waters predominate in the state, a study was made to learn how much soluble arsenic resulted from the combination of oil emulsion and lead arsenate in representative alkaline water used in the several

fruit districts of Oregon. The procedure followed was as described above, except that the alkaline waters were used in place of the distilled water. Oil emulsion No. 9 and lead arsenate A were used in the combination spray. While numerous waters have been used in this study, four only from three different fruit districts of Oregon are reported upon. Table 4 gives the principal ions present in these waters that react with lead arsenate.

TABLE 4. PRINCIPAL IONS IN ORCHARD WATERS THAT REACT WITH LEAD ARSENATE

Water source	Alkalinity as bicarbonate p.p.m.	Chlorides p.p.m.	Sulfates p.p.m.
Medford water No. 1	153	184.2	4.0
Medford water No. 2	329	14.3	Negative
Willamette	65	6.5	Trace
Milton	177	7.5	6.0

The amount of arsenic liberated when the oil emulsion and lead arsenate are mixed in these waters is presented in Table 5.

TABLE 5. SOLUBLE ARSENIC IN COMBINATION SPRAYS OF EMULSION NO. 9 AND LEAD ARSENATE A IN ORCHARD WATERS

Water	Soluble As_2O_5 after shaking 30 min. mg. per liter	6 hrs. mg. per liter	Percentage As_2O_5 soluble after 30 min. %	6 hr. %
Medford No. 1	154	391	9.73	24.6
Medford No. 2	143	229	9.02	14.4
Willamette	86	137	5.41	8.7
Milton	106	151	6.68	9.5

The data in the last table disclose some very startling results. Excessive amounts of soluble arsenic formed and in Medford water No. 1 practically one-fourth of the lead arsenate reacted to liberate its arsenic in the water-soluble state. There would be no question regarding the severity of foliage burn that might be expected to occur from the use of this combination. In fact, last season a block of orchard where this water had been used as a diluent for a lead arsenate-oil emulsion spray was practically defoliated, although a less reactive emulsion had been used.

MEANS OF REDUCING SOLUBLE ARSENIC. If the sale of strongly alkaline oil emulsions is to continue it is necessary to overcome the formation of soluble arsenic. Two lines of procedure were followed in the endeavor to accomplish this. One, by which the arsenic was reprecipitated in an insoluble state; the other by neutralization of the reacting chemicals before the addition of the lead arsenate to the diluted emulsion.

Laboratory tests have shown that the addition of calcium hydroxide (hydrated lime) in comparatively small amounts practically re-precipitated all the soluble arsenic as basic calcium arsenate. When hydrated lime was used at the rate of one-half pound to 100 gallons no water-soluble arsenic formed in most of the combinations reported above. However, when oil emulsions are as alkaline as No. 2 or 11, it is advisable to use one pound of the hydrated lime to each hundred gallons of spray. When the waters also are alkaline in reaction, a pound and a half or even two pounds of lime to the hundred gallons would be advisable. The oil emulsion-lead arsenate combination used with Medford water No. 1 took slightly under ¾ pound of hydrated lime to re-precipitate the soluble arsenic. Since an excess of the calcium hydroxide must be present in order to form the insoluble basic calcium arsenate not less than one pound and preferably two pounds should be used in this case.

The effort to prevent reaction between the oil emulsion and lead arsenate, by partial neutralization, proved very successful in the laboratory. However, it is questionable how practical the procedure would be under field conditions. In the laboratory trials the waters were neutralized and the oil emulsions were partially neutralized with either acetic acid or sulphuric acid. This treatment did not break the emulsion and the water-soluble arsenic was reduced below the danger point. In the combination reported above where Medford water No. 2 was used, both water and emulsion were neutralized and the combination was shaken for three days. Only 9 milligrams per liter of soluble As_2O_5 formed.

Discussion. It is apparent from the foregoing results that foliage burn would occur even on resistant foliage such as apple leaves when certain commercial emulsions are combined with arsenate of lead. Judged from the amounts of soluble arsenic found severe injury probably would have been more prevalent except for the manner of behavior of the summer emulsions when they strike the plant surface. On account of the quick breaking action of the summer emulsions a thin film of oil is deposited on the surface, thus probably protecting the leaf from the burning action of the soluble arsenic. Water run-off of quick-breaking emulsions also is excessive and undoubtedly carries with it much of the soluble arsenic.

While undoubtedly it is necessary to have an excess of ammonium hydroxide or other alkali to dissolve the casein when the latter is used as the principal emulsifying agent, yet it would seem that an excessive amount is now being employed by the manufacturers of certain brands of emulsions. It is suggested that manufacturers endeavor to reduce

the ammonia content to a minimum and preferably not over .2% to .3% free ammonium hydroxide. The reaction with lead arsenate then would be reduced sufficiently that little or no appreciable burning of foliage would result when soft waters are used.

While at present only a small amount of potassium oleate or other soap is now being incorporated in some commercial summer emulsions, this constituent should be kept down to a minimum because of its reaction with lead arsenate.

Commercial spreaders usually contain 50% or more calcium hydroxide. Since many orchardists desire to use spreaders the lime present therein is sufficient to care for the soluble arsenic that forms in most oil emulsion-lead arsenate combinations. However, additional lime to the spreader may be required where alkaline waters are used or when the emulsion is very alkaline. An effective spreader may also reduce arsenical burn in that it promotes water run-off and forms a more uniform film on the surface instead of concentrating in large drops at the tip or edge of the leaf.

For the preparation of a tank of combination spray, the following procedure is recommended:

First. Add the required amount of oil emulsion to the tank and with the agitator going run in the water. By this procedure, if the emulsion is a fairly thick jelly, it is brought to a creamy consistency without lumping.

Second. When the tank is about three-fourths full add one-half to one pound of high-grade hydrated lime for each 100 gallons of spray. If the water is strongly alkaline or is high in chlorides, increase the lime accordingly.

Third. Just before beginning to spray sift in the arsenate of lead and spray out the tank as rapidly as possible. It is preferable to stir the arsenate of lead into a small amount of water before adding to the tank. A film of water thus surrounds each lead arsenate particle and seems to slow up the reaction slightly.

THE EFFECTS OF OIL SPRAY ON THE NAVEL ORANGE

By D. D. Penny[1]

Abstract

The William Bowring navel orange grove at Charter Oak, Calif., which now has a record of nine years of oil spraying shows a normal increased yield with generally excellent vegetative condition. As compared with nine fumigated check trees, the sprayed trees show more vegetative stimulation and more complete scale control. Severe infestations of Black Scale present when treatments started have been reduced greatly and subsequent spray treatments have kept this pest and red spider under satisfactory control.

For the purpose of studying the effects of oil sprays on citrus trees, the California Spray-Chemical Company in 1924 established experimental oil spray plots on the William Bowring fifteen acre navel orange grove located at Charter Oak, Los Angeles County, California, and during the eight year period from 1924 to 1931, inclusive, completed approximately 350 separate tests with these materials. Plots of trees ranging from 9 to several times 9 trees each were employed in these tests. The materials used consisted of commercial spray emulsions and in addition a variety of spray oil stocks which represented about all of the grades of oils from the lightest to the heaviest of the class of oil stocks commonly used on trees in foliage. In these experiments the effects of different strengths of various oils applied at different seasons were studied and in experiments with oils in different emulsifiers, information was obtained as to the influence of these agents on the character of the oil film deposited.

In the actual spraying procedure trees in the earlier tests of 1924 and 1925 received about 15 gallons of diluted spray each in applications made with a small spray machine which developed approximately 250 pounds pressure, but in 1926 and thereafter, applications were made with a larger equipment with greater capacity and ability to maintain pressures of from 450 to 500 pounds which resulted in the use of about 30 gallons of spray to each tree. In the estimation of the writer, under whose direction much of this spraying was done, there was in these tests a tendency, usually, toward overwetting rather than toward underwetting. The 30 gallon average even for trees of the 1931 size being about 5 gallons in excess of what the ordinary commercial spray operator would use.

In studying the effects produced by oils on the trees in the Bowring grove, the results of only a limited number of the various tests need be

[1]Entomologist for the California Spray-Chemical Corp.

considered. By far the larger number of applications made showed results of great similarity and the trees, as far as could be determined, in most cases reacted normally to the treatments, thus demonstrating a strong tolerance of the navel tree for oil sprays generally. On the other hand, a certain few of the tests resulted in reactions that were outstandingly different. The results of these tests will be considered in this paper primarily because of their bearing on the practical use of oil sprays on citrus trees.

It has been repeatedly shown by the Bowring experiments that oil sprays applied to the trees in late spring and early summer caused abnormal shedding of fruit and foliage. In 1926, early July treatments with both light and heavy oils caused fruit drop amounting to 200 oranges to the tree together with excessive defoliation. Late July applications with the same oils showed similar trouble but to a less extent, especially with the light oil. In 1928 and in other years, applications made in June and July with both the light and heavy oils showed reactions much like those of 1926. Applications made later in the summer with these oils gave normal reactions.

In 1927 a very pronounced suppression of bloom followed fall applications of the heavy or 100 seconds viscosity oil. This same effect has been observed to a less extent in other years from late applications of the heavy oil. Light oil of 55 seconds viscosity put on at the same time seldom has shown bloom suppression. From these results the conclusion is drawn that quantity of bloom, which appears following the application of oils in the fall and early winter, is somewhat in proportion to rate of volatilization of the oils, which is known to be much slower with the heavy oil than with the light and which is materially reduced with all oils in winter months. Trees with excessive bloom suppression can reasonably be expected to produce less fruit than trees with a more normal bloom, but it is of interest to note in connection with the bloom suppression obtained in 1927 that while the number of fruits produced was considerably less than normal on trees affected, the fruits remaining increased in size to such an extent over fruits from the normal trees that the number of boxes picked from 9 trees in plots with reduced bloom was equal to the number of boxes of fruit picked from 9 trees in plots not so affected.

An experiment to determine the amount of dead wood caused by oil sprays was begun in 1929 and was continued in 1930 and 1931. At the start of this experiment, two plots of 9 trees each were very carefully pruned and all dead wood of even match size was removed from both.

One row was then fumigated and the other sprayed with a 1.66 per cent dilution of a 70 seconds viscosity oil. In the years 1930 and 1931, the same treatments were repeated. Observations in April 1932 showed no difference in the amount of dead wood in these plots, there being a small accumulation of dead wood in both plots which appeared to be of normal occurrence probably formed in a natural shading out process.

While the results of this experiment show little connection between dead wood formation and oil sprays it cannot be said that these results always obtain. Not infrequently in commercial spraying practice, oil sprays have been known to cause small amounts of dead wood and occasionally severe damage of this type occurs. Such injury has been observed in varying degrees of severity in the Bowring experiments which was caused by over oiling of the trees or the application of oils in quantities greatly in excess of the amount needed for good coverage and which the tree could not readily throw off. Over oiling has been brought about both deliberately and accidentally in the course of these experiments. In 1926, a plot of trees was first carefully pruned to remove dead wood and then sprayed with an excessive dose of a 2 per cent dilution of the 100 seconds viscosity oil. The trees in this application receiving 50 gallons of diluted spray each. This treatment not only resulted in the formation of dead wood but caused in addition severe defoliation followed by a decided bloom suppression the following year. As might have been expected liberal applications of the same oils in the casein or quick breaking type of emulsion were found to cause over oiling more readily than liberal applications of the same oils in light emulsions. Very light oils in rather high doses failed to cause over oiliness in any type of emulsion. From the standpoint of economy, it would seem wise to use oils in emulsions of the quick breaking type which deposit a large part of their oil on the tree, but from the standpoint of injury it would appear, according to the results obtained, that it would be more rational to use emulsions that spread the oils thinly and uniformly over the tree even though this were accomplished at the expense of losing a great portion of oil in the run off from the tree.

Tests of various emulsifiers designed to study the influence of these agents on the character of the oil film deposited showed decided advantages in favor of whale oil soap emulsions which were found to deposit an unvarying light film of oil and at the same time to thoroughly wet rough and checked bark surfaces and other surfaces, usually wetted only after prolonged application of spray. The heavy oil applied in this type of emulsion showed little penetration into the foliage and fruit.

Late applications of this same oil in soap emulsions gave no bloom suppression. Both of these results indicated a lighter and more uniform film compared to that obtained with the ordinary quick breaking type of emulsion.

Information gained from the study of certain plots in the Bowring grove has shown that oils may be made to play an important part in the maintenance of vigorously growing trees. Plots sprayed for a period of years in summer with oil of 100 seconds viscosity when compared with plots sprayed continuously in the same seasons with the light oils, seemed to have shown, from year to year, a better quality and a greater abundance of foliage. This improvement in foliage appeared to be in proportion to the stimulation of growth occasioned by the oils and which became apparent, generally, a few weeks after the application. This stimulation of growth, which is characteristic of oil sprays, was found in the Bowring grove to occur to a greater extent some years than others and was generally more pronounced with the heavier oils than with the lighter oils. The amount of bloom which developed on the summer sprayed heavy oil plots with pronounced vegetative stimulation was occasionally less than the normal trees showed, especially in years of light bloom generally, but the crops estimated on the trees in these plots appeared to be equal to those of the light oil plots.

In years of rather heavy bloom in the district, such as occurred in 1927, the summer applications of the 100 viscosity oil resulted in an excellently balanced condition of blossom and foliage, while at the same time the light oil showed the more normal, weaker, bouquet-like bloom, characterized by a greater proportion of blossoms to foliage developed.

Trees sprayed in February each year with a 2 per cent dilution of the heavy oil, in most years, showed less vegetative stimulation and less influence of the oil on the bloom than did the trees of the summer sprayed plots.

The effectiveness of oil sprays as a class in the control of black scale has been well demonstrated in the Bowring grove. The very severe infestation of scale which existed in this grove at the outset of operations in 1924 was after a few years greatly reduced and subsequent treatments kept this insect to a minimum. Comparatively high doses of oil sprays were necessary in the first few years to bring the black scale under control, but in later years, especially after adopting the use of more liberal amounts of spray to the tree and after the scale population had been materially lessened, light doses of even the light oil were found to be sufficient to maintain the trees in a clean condition. Because of the great

reproduction of black scale, however, it was found that a yearly treatment was necessary, for even the clean trees allowed to go more than a year without treatment had infestations built up to damaging proportions.

Experience in the control of red spider in these tests showed that oils of 65 seconds viscosity or heavier were necessary to kill the eggs of this pest. In 1927 and 28, a year of severe spider infestation, the light oil of 55 seconds viscosity, even in 6 per cent dilution, failed to give more than a temporary control of this insect while heavier oils at much less strength gave complete control. The oil of 65 seconds viscosity was found to give a good control of black scale and red spider in repeated tests, and in general was found to be a satisfactory oil. This oil showed, however, to a limited extent only, the effect of improved vegetative state similar to that resulting from the use of the heavy oil of 100 seconds viscosity. The effect of the 65 seconds oil in this respect being more like that of the light oil than that of the heavy oil.

Yearly records of yields were never consistently obtained from the variously sprayed plots in the Bowring grove so that definite figures showing the influence of oils on yield are not available. From the stardpoint of the influence of oil sprays as a class, however, the production records of the Bowring grove are of interest. These records which are given below and which were obtained from the Charter Oak Citrus Association begin with the year 1922, or the year previous to the use of oil sprays on the Bowring grove,[2] and extend up to and include the year 1932:

1922	1984 boxes.	1928	5508 boxes.
1923	2551 boxes.	1929	10500 boxes.
1924	751 boxes.	1930	3615 boxes.
1925	5294 boxes.	1931	6590 boxes.
1926	1995 boxes.	1932	6250 boxes.
1927	4910 boxes.	1932*	6250 boxes.

*With an estimated loss of 1000 boxes on the ground from decay.

These production records show what appear to be normal fluctuations in yield from year to year with a definite tendency toward increase in latter years. There is no evidence of decreasing tolerance of the trees for oil sprays nor evidence of a general deterioration which effects would have manifested themselves, undoubtedly, in the records of production. The Bowring crop in 1929, the year the bumper crops of oranges in California, was the largest the grove has ever produced, the

[2]This grove was sprayed commercially with refined oil spray in 1923.

total of 10,500 boxes making an average of about 10 boxes of fruit to the tree, which was about 100 per cent more fruit than the grove had produced in any previous year. It seems significant that this crop which was, indeed heavy, appeared after 6 years of continuous uninterrupted oil spraying.

At the time of abandonment of experimental operations in 1931 the generally fine tree condition which prevailed, as shown by excellent quality and abundance of foliage present, permitted this grove to compare favorably with the best groves in the district, which in itself may be considered very good evidence of the ability of the navel grove to prosper under the influence of a continuous oil spray program.

EXPERIMENTS WITH OIL SPRAYS USED IN THE CONTROL OF THE CALIFORNIA RED SCALE, *CHRYSOMPHALUS AURANTII* (MASK.) (HOMOPTERA: COCCIDAE) ON LEMONS

By WALTER EBELING, *University of California Citrus Experiment Station, Anaheim, Calif.*

ABSTRACT

Data are presented which indicate that the effectiveness of oil sprays is proportional to the heaviness of the oil and the percentage of oil used in the spray, and inversely proportional to the amount of spreader used in the spray. Within the range of sulfonation of the oils used in the tests, no significant difference in insecticidal efficiency of the sprays was caused by difference in sulfonation of the oils. Injury to foliage was found to be proportional to the heaviness of the oil and the percentage of oil used in the spray, and inversely proportional to the amount of spreader used and the sulfonation of the oil.

During the years 1930 and 1931, the University of California Citrus Experiment Station made a series of experiments to determine the effectiveness of oil sprays in the control of red scale on lemon trees. In 1930 experiments were made in 18 groves in Orange County and in 1931 experiments were made in 13 groves in Orange and Los Angeles counties. In 1930 six tests were made in each grove; five tests were Tank Mix spray, using heavy oil at 1½, 2, and 2½ per cent, and medium oil at 2 and 2½ per cent; and one test was proprietary emulsion at 2 per cent. The same plan was also followed in 1931 except that the use of 2½ per cent heavy oil was discontinued and 1 2/3 per cent heavy oil

was included in the spray tests. One 300-gallon tank of each spray was applied in each test.

The approximate distillation ranges of the oils were as follows:

Degrees Fahrenheit	Medium oil Per cent distilled	Heavy oil Per cent distilled
575	5	0
600	18	4
625	38	19
650	58	40
675	73	64
700	85	80
725	93	90

Blood albumen spreader was used at the rate of 4 ounces to 100 gallons in the tank mixture spray. This consisted of one part of Grade A powdered blood albumen and three parts of fuller's earth. With a few exceptions, the proprietary emulsions were the heavy grade generally used in spraying lemons and were used at 2 per cent concentration.

All materials were applied by commercial spray operators. The spray rigs were first tested in regard to agitation, pressure, and discharge of the spray guns, in order to insure optimum conditions for application. The application was supervised by the writer, who made it a point to see that as nearly as possible a 100 per cent coverage of all parts of the tree was effected.

METHOD OF DETERMINING RESULTS. In 1930 a preliminary study of the effectiveness of the sprays in killing insects on the branches, green twigs, leaves, and fruit was made.[1] It was found that by far the greatest survival occurred on the branches, and therefore the branches were adopted as a standard unit upon which to determine the effectiveness of the spray treatment. The insects on twenty units of branches were counted on ten trees in each plot. A unit of branch comprised from two to four inches of bark as seen from one aspect. By using this method, from 2,000 to 3,000 insects were usually counted on each plot. In 1931 counts were made on the fruit as well as on the branches.

The counts were made about six weeks after treatment. This period of time is sufficient to allow the body contents of the insects to become discolored or dry so that the insects may easily be determined whether dead or alive by crushing them with a dissecting needle or the small blade of a pocket knife. An effort was made to confine the counts to in-

[1]Ebeling, Walter. 1931. Method for determination of the efficiency of sprays and HCN gas used in the control of the red scale. Calif. State Dept. Agr. Mo. Bul. 20 (10-11):669-671.

sects in the third stage of development because the insects of this stage are the most conspicuous and also are the most difficult to kill by oil sprays. In practice, however, many second stage insects were also counted. It is sometimes difficult to differentiate between the two stages, particularly in making counts on the bark, where the bodies of the insects often overlap or are conformed to irregularities in the surface of the bark.

In 1930 no counts were made previous to treatment to ascertain the natural mortality. In 1931, however, counts were made both before and after treatment. In Table 1 the term "survival" refers to the percentage alive, based on the total number of insects counted after treatment. The percentage "net survival" is based on the number of insects alive before treatment and the number alive six weeks after treatment.

TABLE 1. SUMMARY OF THE RESULTS OF EXPERIMENTS MADE DURING 1930 AND 1931 IN SPRAYING LEMON TREES FOR THE CONTROL OF THE CALIFORNIA RED SCALE

Spray	Percentage of insects surviving treatments				
	1930	1931			
	Branches	Branches		Fruit	
	Survival	Survival	Net survival	Survival	Net survival
Tank Mixtures					
Heavy oil 1½%	29.19	18.87	27.23	6.75	7.59
Heavy oil 1⅔%	——	13.29	18.20	4.97	5.51
Heavy oil 2%	14.48	7.34	10.53	3.70	4.16
Heavy oil 2½%	5.79	——	——	——	——
Medium oil 2%	19.80	8.58	12.68	4.59	5.11
Medium oil 2½%	9.75	5.49	8.13	2.21	2.54
Proprietary emulsions 2%	26.60	16.63	23.50	5.29	5.82

RESULTS OF EXPERIMENTS. The data of Table 1 indicate that the effectiveness of the sprays was proportional to the heaviness of the oil and the percentage of oil in the spray. Increasing the concentration from 1½ to 1 2/3 per cent or from 1 2/3 to 2 per cent resulted in greatly increased effectiveness of the spray. The emulsions contained only about 83 per cent oil, the remainder being water and emulsifier and, when used at a concentration of 2 per cent, the spray contained only about 1 2/3 per cent actual oil. It would be expected, therefore, that 2 per cent emulsion would give about the same degree of control as 1 2/3 per cent oil used in the tank mix spray, as is borne out, within the bounds of experimental error, by the data given in the table.

INSECTICIDAL EFFICIENCY VS. SAFETY TO TREE. In September, 1930, an extensive experiment was made in a 10-acre lemon grove with the

object of determining the relation of (1) the heaviness of the oil, (2) the purity or sulfonation of the oil, and (3) the oil-depositing quality of the spray, to the insecticidal efficiency of the spray and injury to the tree resulting from the spray. All together 42 tests were made, an average of 12 trees being used in each test.

The specifications of the oils in regard to heaviness were the same as those previously mentioned. Three grades of purity were represented, namely, 98–100% unsulfonatable, 90% unsulfonatable, and 86% unsulfonatable. These grades included the entire range of purity of oils then in use in spraying citrus trees.

All the spray was applied in the form of tank mixtures. Tests were made with three sprays, (1) oil and water only, (2) oil, water, and blood albumen spreader at the rate of 4 ounces to 100 gallons, and (3) oil, water, and blood albumen spreader at the rate of 8 ounces to 100 gallons.

The results of the experiments are given in Table 2. It may logically be expected that among the various oils used, those low in sulfonation would be the more effective against insects because of their greater unsaturated hydrocarbon content. However, no correlation was found between sulfonation and insecticidal efficiency. Insecticidal efficiency was dependent upon the heaviness of the oil, percentage of oil used in the spray, and the amount of spreader used in the spray. Although the spray containing no spreader was apparently equal in insecticidal efficiency to the one in which 4 ounces of spreader was used to 100 gallons of spray, the latter was preferable because of less injurious effect upon the foliage. Increasing the amount of spreader to 8 ounces to 100 gallons resulted in greatly reducing the effectiveness of the spray because of the lower amount of oil deposited.

The degree of injury was determined by the number of leaves dropped by the spray. Three weeks after the spray was applied, a count was made of the number of leaves under each of ten trees in each plot. Only those leaves were counted which showed by their appearance that they had dropped since the application of the spray. Although leaf drop may not be a satisfactory criterion of the total amount of injury caused by an oil spray, it is at least a reliable index of the comparative effects of different sprays.

The accompanying chart shows the amount of leaf-drop caused by the sprays. It will be noted that the injury to the tree as evidenced by the leaf drop was proportional to the heaviness of the oil and the per-

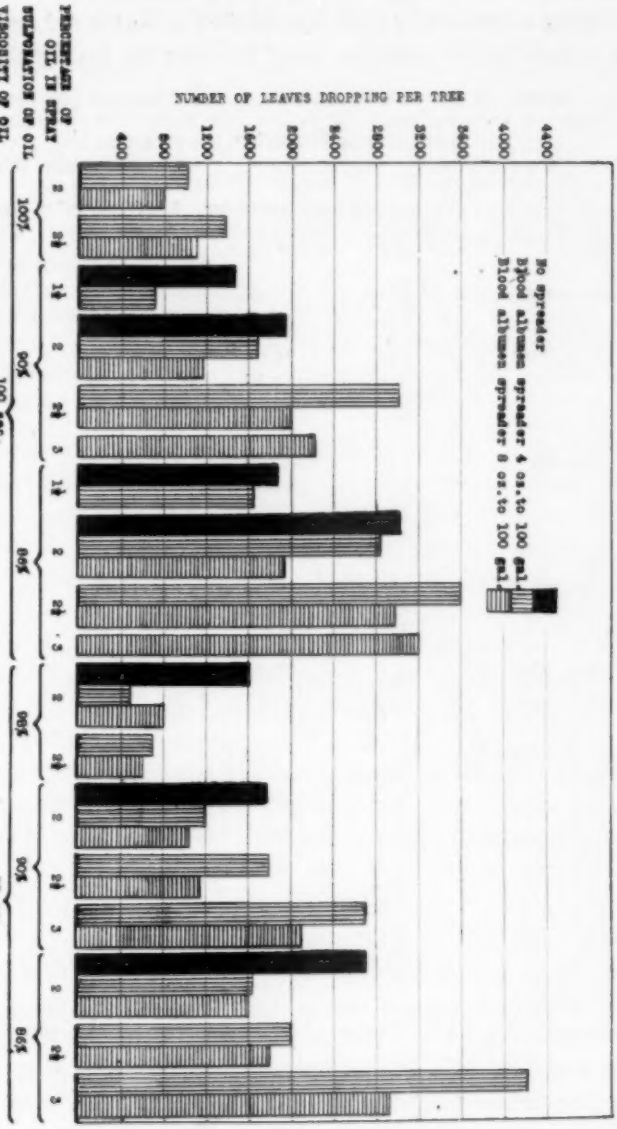

Fig. 64.—Chart showing leaf-drop caused by oil sprays.

centage used in the spray, and inversely proportional to the sulfonation of the oil and the amount of spreader used in the spray.

In selecting a spray to be used against the California red scale on citrus trees, a proper balance must be found between the insecticidal efficiency

TABLE 2. SUMMARY OF RESULTS OF EXPERIMENT IN SPRAYING FOR THE CALIFORNIA RED SCALE ON LEMON TREES. PERCENTAGES REFER TO INSECTS ALIVE ON THE BARK ONLY. FROM SMITH AND EBELING[1]

Specifications of oil	Percentage of oil in spray	No spreader Insects alive per cent	Blood albumen spreader 4 oz.–100 gals. Insects alive per cent	Blood albumen spreader 8 oz.–100 gals. Insects alive per cent
Heavy oil				
Sulfonation 100%...	2	——	25.72	31.51
	2½	——	6.19	10.93
Sulfonation 90%....	1½	25.21	42.11	——
	2	13.13	13.75	27.84
	2½	——	2.36	12.84
	3	——	——	3.54
Sulfonation 86%....	1½	37.00	35.77	——
	2	18.55	8.35	24.94
	2½	——	3.59	11.88
	3	——	——	6.63
Medium oil				
Sulfonation 98%....	2	9.68	17.82	15.14
	2½	——	7.73	15.84
	3	——	6.15	15.87
Sulfonation 90%....	2	21.10	25.36	30.34
	2½	——	13.35	19.08
	3	——	8.00	13.24
Sulfonation 86%....	2	14.00	8.78	21.91
	2½	——	8.23	16.20
	3	——	3.22	11.14
All tests with 100 viscosity oils.....	1½	30.17	39.54	——
	2	16.49	15.27	27.78
	2½	——	4.28	11.78
	3	——	——	5.35
All tests with 80 viscosity oils.....	2	14.99	16.89	22.99
	2½	——	9.94	17.02
	3	——	6.50	13.03

[1]Smith, R. H., and Ebeling, Walter. 1930. Additional report on experiments with oil spray for red scale. California Citrograph 16 (10):451, 496.

and the safety of the spray. In general, the qualities of the spray making for greater safety also reduce the insecticidal efficiency of the spray. An important exception, however, is sulfonation. It appears that an oil of the highest sulfonation compatible with reasonable cost may be used without an appreciable reduction in the degree of control obtained.

PRODUCTION AND SPREAD OF THE WOOLLY APHIS PARASITE, *APHELINUS MALI*, IN THE HOOD RIVER VALLEY

By LEROY CHILDS and D. G. GILLESPIE, *Hood River Experiment Station, Hood River, Oregon.*

ABSTRACT

From an initial introduction of 550 woolly apple aphis parasites from Michigan in 1929 a total of 92,000 have been reared and liberated in the Hood River Valley and other points. The majority are liberated in the adult stage after being reared in caged apple trees.

The parasite is now thoroughly established in over 40 Hood River orchards and is spreading rapidly.

Degree of woolly aphis control by the parasite has been demonstrated.

Seasonal history of the parasite has been closely checked for two seasons, showing eight complete generations in 1930 and nine in 1931.

Unusual success in the first introductions of the woolly apple aphis parasite, *Aphelinus mali* Haldm., in 1928 and 1929, and further success in initial large scale rearing experiments led the writers to predict a fairly rapid dissemination of the insect throughout the Hood River Valley within the next three years. That this dissemination should result in any marked degree of woolly aphis control was a somewhat debatable question, even though preliminary tests, undertaken in the Hood River Experiment Station orchard, gave promise of future achievement. Any doubts regarding large scale production of the parasite was set at rest by the fall of 1930 when a total of 28,700 adults and parasitized woolly apple aphis were reared at Hood River and were liberated in the valley and other western points. The season of 1931 saw this production increased to a total of 63,000 parasites actually liberated, thus making a grand total of 91,700 for the two years. A still further increase in liberations is expected for the present season.

PARASITE LIBERATION AND ESTABLISHMENT IN HOOD RIVER ORCHARDS. Orchards of the Hood River Valley have received the bulk of the parasites to date. It has been found most feasible to rear them through to the adult stage before making distribution. Thirty-three different orchards well distributed throughout the Hood River Valley received a total of 27,780 parasites in 1930; an average of 842 per orchard. The next season saw 58,000 parasites—all adults—liberated in about 42 different orchards, giving an average of 1,383 per orchard.

A careful check for establishment of the parasite was undertaken dur-

ing the summer and fall of 1931 in most of the orchards in which 1930 liberations were made. It was found that complete establishment had resulted in all but two orchards. In the majority of cases *A. mali* had spread to a distance of several tree rows. In some instances adults and parasitized aphis could be found throughout the whole orchard. In more than one instance they were discovered in new orchards over one-quarter mile away.

REARING AND LIBERATING METHODS. Small muslin covered frame cages, 30x16x11 inches, having sliding glass tops, and placed over boxed apple seedlings, were first used to rear *A. mali* for liberations in 1929. These were discarded the following year and much larger cages used. Permanent wooden frames were erected over eight-year-old Delicious apple trees, and were covered with a fairly heavy grade of unbleached muslin, held securely in place with lath strips. A 5-foot door was placed on the east side of each cage.

The three trees selected for caging were, as far as could be ascertained, free from woolly aphis, because one could then be reasonably sure that no aphis predators, the bane of parasite rearings the previous season, would be present.

Steps were taken to infest trees with woolly aphis as soon as they were enclosed. The most satisfactory method was as follows: about 35 test tubes, or glass vials of similar size, were bound to branches in all parts of the tree. Apple tree suckers or twigs, heavily infested with woolly aphis, were brought to the cage. Each twig was carefully examined and all insect predators removed. Two or three twigs were then placed in each tube or vial and closely bound to the limbs of the tree. The containers were then filled with water and were kept filled for a period of three weeks. Transfer of woolly aphis to the tree was usually very satisfactory. Reproduction was rapid and the tree was soon covered with the parasite host. When this stage was reached the parasites were let in—between one and two thousand adults per cage.

Parasitism of the caged woolly aphis increased rather slowly at first, but picked up very rapidly towards the end of the first summer. Reproduction in one of the cages was so high throughout the month of August that the collection of 500 or more parasites per day did not seem to affect their numbers.

The cages constructed in 1930 were used again in 1931 and will last through the present season. A new muslin covering may be needed every other year, but this expense can be obviated if the old covering is removed from the frame each fall and stored in some dry place.

COLLECTION AND LIBERATION OF THE PARASITE. A simple but satisfactory piece of apparatus was devised for catching the adults. This consisted of a 4-inch test tube with a small hole blown in the rounded end, to which was attached a 2-foot rubber hose with a small glass mouth pipe on the other end. A piece of cotton was fastened to the end of the hose attached to the test tube, and another piece was plugged in the test tube itself, thus keeping the insects from being drawn up into the hose. With this apparatus the adults were readily caught by suction. The tube was emptied by simply tapping the sides and allowing the insects to fall back through the hole which they entered into another test tube of similar size. This tube was then plugged with cotton and was ready to be taken to the orchard for liberation purposes.

Every effort was made to release the parasites just as soon as possible after collection, especially in hot weather.

CHECK ON DEGREE OF WOOLLY APHIS CONTROL. The debatable question as to whether any marked benefit would be obtained from large scale liberations of the parasite was one that was cleared up by a series of observations instituted by the senior author in 1930. In the fall of the year, when the parasite had already done its best work, a comparison was made between the woolly aphis population in the two orchards where the first parasite liberations were made in 1929 and nine other orchards in which no parasites had been liberated.

The method of determining the aphis population in the different orchards was to select 10 Newtown apple trees per orchard, cut ten suckers or twigs, at random from each tree, and then count the woolly aphis at ten leaf bases on each twig, thus counting 1,000 leaf bases per orchard. The observations were continued in 1931, two complete checks being made.

In 1930 the average woolly aphis infestation per tree for all the check orchards was 30.2 per cent and for the two orchards with parasites 11.4 per cent, or a difference of 18.8 per cent. It is believed, at this time, that the results obtained are sufficiently striking to show that there was considerably less aphis infestation in orchards having parasites than in those not having them.

Random observations made at this time (June, 1932) of the parasite at work in the orchards tend to confirm the foregoing figures. Many growers have remarked, especially during the current season, as to the scarcity of woolly aphis in their orchards, and the large numbers of parasites and parasitized aphis present.

LIFE HISTORY NOTES. Hood River's climate seems especially suitable to the rapid production of *A. mali*. A total of eight complete generations in 1930 and nine in 1931 have been reared in both laboratory and outdoor cages. The extra generation of 1931 was apparently due to the warmer later fall. In the orchard there is a constant overlapping of generations, probably brought about by the great difference in time of emergence of adults. There has been as great a difference as 20 days in emergence of adults from woolly aphis in which parasite eggs were laid on the same day.

CONCLUDING REMARKS. A paper of this type, confined mainly to generalities, does not permit an intimate discussion of many of the factors which go to make *A. mali* what might be termed a model insect parasite. Its freedom from hyperparasites, short life cycle, unique host selection, ability to survive for an almost indefinite period in cold storage, immunity to orchard sprays, etc., make its presence highly desirable in any orchard section, where the woolly apple aphis is either an individual apple pest or a prime factor in the spread of perennial canker (*Gloeosporium perennans* Zeller and Childs).

LIOTHRIPS VANEECKEI PRIESNER, A RECENTLY DISCOVERED PEST OF LILY BULBS

By RALPH SCHOPP and CHARLES F. DOUCETTE, *U. S. Bureau of Entomology, Sumner, Washington.*

ABSTRACT

Liothrips vaneeckei was originally described in 1920. Its distribution at present includes Holland, Austria, Italy, France, Belgium, England, Russia, Japan, Ceylon, Canada and the United States. In the United States it is known to be present in California, New York, North Carolina, Oregon and Washington. Native bulbs of *Lilium washingtonianum* of considerable age growing in an isolated section of the Santiam National Forest, Oregon, were found infested. A decided preference for this species of lily has been observed in cultivated plantings. Brief notes concerning the several stages of the insect are given.

Liothrips vaneeckei was described in 1920 by Priesner (3) from specimens collected in Holland dated 1915. The finding of this insect in lily bulbs in the Pacific Northwest in 1930 and 1931 prompted an investigation at the Sumner, Washington, field laboratory of the Bureau of Entomology. A preliminary discussion to give the present status is here presented.

In addition to the presence of this thrips in Holland, Priesner (4, p. 221) states that it is also present in Austria, Italy, Japan, and North America. The records of the United States Plant Quarantine and Control Administration show that it has been intercepted in lily bulbs from Canada, France, Russia, Holland, and Italy, and on the orchid *Vanda roxburghi* from Ceylon. J. R. Watson, Entomologist of the Florida Agricultural Experiment Station, in correspondence with the Plant Quarantine and Control Administration, states that it is present in England and Belgium.

Published records indicate the presence of this species in only two States in the United States, California (2, p. 169; 5, p. 29) and New York (1, p. 180). Its presence in Oregon has been observed by the writers, and inspection officials in that State have found lily bulbs shipped from North Carolina to be infested. In addition, J. R. Watson states, in correspondence, that he has material from Washington State. It is felt that the distribution in the United States is probably much more extensive and that as a more general search is made it may be found in localities other than those now on record.

Of particular interest is the discovery that native bulbs of *Lilium washingtonianum* in the Santiam National Forest, Oregon, carried infestation. This condition was reported to the writers in the summer of 1931 by Mr. P. R. Oshanic, a lily grower, who stated that he had observed these thrips in native bulbs for approximately ten years past, and a trip to the locality mentioned, under his guidance, confirmed his observation. Specimens were determined by Dr. H. Morrison, Bureau of Entomology. All explanations of the presence of *Liothrips vaneeckei* in this rather isolated region, several miles from highways and at an elevation of 3,500 to 4,500 feet, seem to be without basis, except the one that the thrips are native in this section. A further survey of the native lily bulbs in the Pacific Northwest is expected to furnish more evidence on this particular phase of the matter.

In cultivated plantings the observations show that there is a decided preference for bulbs of the Mt. Hood lily, *L. washingtonianum*. The writers have also observed the thrips in the following species of Lilium: *L. pardalinum*, *L. occidentale*, *L. umbellatum*, *L. sargentiae*, *L. bulbiferum*, *L. superbum* and *L. humboldti*.

It is to be expected that further observations may furnish additions to this list. *L. regale* appears to be immune, since bulbs of this species growing very close to other infested bulbs have been frequently examined and no indications of *Liothrips* found in them.

Our present information indicates that the thrips live and feed only between the scales of lily bulbs except for the one instance where it is reported on an orchid. All stages are usually found in the bulbs. The means of spread has not yet been determined, further than the migration from bulb to bulb in storage. Wings are well developed, but the writers have not observed any in flight, nor have sweepings of vegetation around infested plantings yielded any specimens.

The direct injury caused by the feeding of the thrips does not appear to be very great. It is apparently confined to the epidermal cells of the bulb scales which turn light brown in color owing to drying after feeding.

Liothrips is one of the genera in the suborder Tubulifera, and thus it is difficult to distinguish between male and female. The adults are comparatively large, ranging from 2.4 to 2.9 mm. in length. The females are larger than the males. At first glance the entire insect appears to be a glossy black. Close inspection shows that the antennae, except base and tip, and the lower part of the tibiae, and tarsi are yellow. The wings are strongly fringed on both sides, with transparent membrane and no well-developed veins. On the anterior margin of the forewing there is a dark area near the base bearing three strong spines.

Some evidence of parthenogenesis has been obtained. One female, reared through larval and pupal stages in an individual cage at room temperature, in the course of its 76 days of adult life laid 43 eggs, 11 of which hatched. These larvae, however, were not reared to adults to determine their sex. The life-history studies indicate that the females start egg deposition 8 to 10 days after emergence, lay eggs singly, one or two a day, and may live for a considerable period.

The eggs as deposited are slightly sticky and adhere lightly to the surface of the bulb scale. They are nearly cylindrical in shape with rounded ends, measure about 0.5 mm. in length, and are half as wide as long. The color is light amber, and the chorion is finely reticulated. The data accumulated on the incubation period give a range from 6 to 17 days with an average close to 12. An occasional individual requires a longer period, the maximum recorded being 25 days.

The hatching larva cuts a circular hole in the chorion near one end, and begins walking around and feeding as soon as it is free. The first-instar larvae are pinkish white except for the dark head, dark and somewhat mottled thoracic plates, and the darkened abdominal tip. The legs and antennae are almost transparent. The first stadium of 26 larvae was 7 to 19 days. Most of these molted after a period of 8 to 13 days, and the average length of the instar was about 11 days.

The second-instar larva is similar to the first except for its larger size and the fact that the more heavily chitinized areas are larger and more nearly black. The length of the second stadium of 19 larvae ranged from 9 to 25 days, most of the larvae pupating between 10 and 14 days; the average was close to 13 days.

There seems to be no prepupal stage in this species, for no evidence has been noted of any intermediate stage between the larva and pupa.

The pupa is mobile, and when it first appears the entire insect is pinkish. The wing pads, red eye spots, red ocelli, and the backward-curved antennae, which are not free to move, appear in two or three days after pupation. The eye spots and ocelli later become brown, and the day before emergence the wing pads and the edges of the abdominal segments darken. The pupal stage of 14 individuals ranged between 10 and 13 days with an average of about 12 days.

It is hoped that this discussion of this little-known subterranean thrips will help in developing an understanding of it among entomologists and others.

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THE VAPOR-HEAT TREATMENT AS APPLIED TO THE CONTROL OF NARCISSUS PESTS

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ABSTRACT

The vapor-heat method is adaptable for the treatment of narcissus bulbs for the control of bulb flies and mites. A two-hour period of treatment at 111° F. appears to be the minimum requirement for control of the larvae of the lesser bulb flies (*Eumerus* spp.) and of the greater narcissus fly (*Merodon equestris* Fab.). Control is also obtained of the two species of mites, *Rhizoglyphus hyacinthi* Bdv. and *Tarsonemus approximatus* var. *narcissi* Ewing, which are frequently found on narcissus. Bulbs treated at the optimum time during the dormant period were forced under glass and produced good flowers. Planting stock so treated is benefited through the more vigorous growth caused thereby and an additional increase in weight in the resultant crop.

Apparently the first definite suggestion concerning the use of vapor heat for insect control was made by Dr. D. L. Crawford, on the basis of studies on the Mexican fruit fly conducted by him in Mexico in 1913–14. Dr. Crawford demonstrated that moist heat could be used to kill fruit-fly eggs or larvae in fresh fruit without injuring it. This method, the commercial application of which was pointed out by Crawford, was not followed up. It was redeveloped, however, in Florida under Dr. A. C Baker, of the U. S. Bureau of Entomology, and given commercial application by Dr. L. A. Hawkins, of the Bureau of Plant Quarantine, in connection with the Mediterranean fruit fly campaign of 1929–30, as an extra precaution to insure freedom from infestation in citrus fruits.

The vapor-heat method, however, is a new conception of an old idea. For the insecticidal effect, this method uses heat which is carried by moisture-laden air. Dry air carries a comparatively small number of calories, whereas water carries a maximum. Air saturated with moisture has some of the advantages of both and lacks their disadvantages. The wetting of the bulbs in the hot-water method is especially objectionable in that considerable care is required in the handling and drying of the stocks after treatment. Hot-water sterilization of nursery stock and bulbs has been practiced for some time both in Europe and America (1, 2, 3, 5, 7, 8, 9).

In 1930 experimental work was inaugurated at Sumner, Wash., for the purpose of determining whether the same process could be applied in the treatment of various insects and mites infesting narcissus and other flowering bulbs.

The equipment and method of procedure employed in the treatment of narcissus bulbs is similar to that used in Florida in sterilizing citrus fruits. It is briefly described in administrative instructions issued by the Plant Quarantine and Control Administration in October, 1929, under the Mediterranean fruit fly quarantine. Further details are given in papers by Mackie (6) and Hawkins (4). A description of the equipment and procedure used in these tests follows.

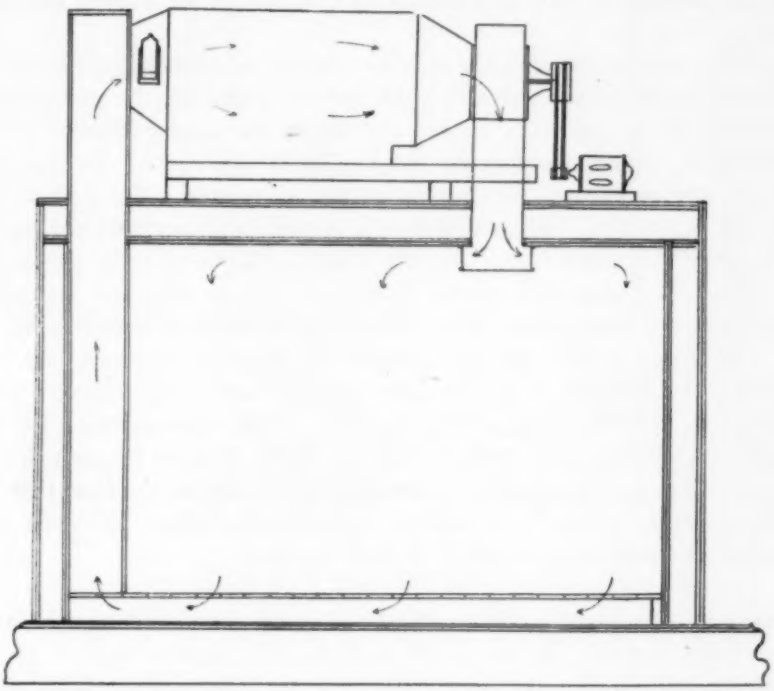


Fig. 65.—Diagrammatic side view of the equipment used for vapor-heat treatment. The double-wall construction is shown, also the position of the false floor which allows free passage of the air to the vent at one side. The vent leads to the mixing chamber at the top, where the air is heated by the steam spray. The motor-driven fan blows the air back into the top of the room, where it is spread by the grid plate beneath the opening.

EQUIPMENT AND PROCEDURE. The experimental treating room used in these tests (Fig. 65) is 12 by 12 by 8 feet, although the size is optional up to 24 feet as long as the room is square. Outside of and just above the room is the mixing or conditioning chamber, where steam and water are introduced into the air system. The walls of the room are

double, the inside portion covering a layer of insulating board. The entire inside of the room is waterproofed with paraffin applied in liquid form. The floor is of sheet metal with a drain at the lowest point, and a false floor raised 6 inches above this is made with 1-inch spaces between the boards. The supports of the false floor are made of 2 by 6 inch "leaders" systematically arranged to diverge radially from the center of one wall, at which point the air is taken from the room. This arrangement causes equal quantities of air from all parts of the room to be drawn through a vent, which leads up this wall to the mixing chamber above.

In the mixing chamber the air from the room is conditioned by being drawn through steam and cold-water sprays. These may be so regulated that the air is heated as desired and leaves the mixing chamber fully saturated. A large multivane fan located at one end of the chamber forces the air through an opening in the ceiling and a flat grid immediately below this opening disperses it evenly to all parts of the top of the room. The air in the treating room is displaced three times per minute. A thermostat placed in the air stream entering the room regulates the steam valve, thus maintaining an accurate temperature.

The temperature in the room and in the bulbs is constantly checked throughout the period of treatment by resistance thermometers connected to a control box on the outside. These thermometers are inserted in the centers of bulbs, which are placed in trays throughout the room. The treatment period is recorded as starting at the time that all thermometers register the desired temperature, which indicates that the entire load has been heated to that degree.

Effect of Treatment on Insects. Sufficient data are not yet available to warrant recommendation of a definite period of treatment for insect control. In the season of 1930, 110° F. was selected as the standard treatment temperature, but during the following season the temperature was raised one degree, *i.e.*, to 111° F. Tables 1 and 2 show the results of representative tests with the larvae of both the greater and the lesser bulb flies, *Merodon equestris* Fab. and *Eumerus* spp., respectively. With one exception, a two-hour treatment at temperatures of 110–111° F. was sufficient for complete control. Incidentally the same treatment was found to be more than sufficient to produce complete mortality of the two species of mites found commonly in bulbs, *i.e.*, *Tarsonemus approximatus narcissi* Ewing and *Rhizoglyphus hyacinthi* Bdv. The experimental results indicate that from 30 minutes to one hour is sufficient to kill these mites.

TABLE 1. MORTALITY OF LARVAE OF *Merodon equestris* AND *Eumerus* SPP., RESPECTIVELY IN NARCISSUS BULBS TREATED WITH VAPOR HEAT; TESTS IN 1930

Temperature °F.	Duration of treatment Hours	*Merodon equestris* Condition of larvae Dead Number	Alive Number	Mortality Per cent	*Eumerus* spp. Condition of larvae Dead Number	Alive Number	Mortality Per cent
100	(a)	3	15	16.6	76	500	13.1
100	(a)	3	21	12.5	23	418	5.2
105	(a)	2	13	13.3	2	267	0.5
105	(a)	1	13	7.1	58	152	27.6
110	(a)	3	7	30	172	164	51.1
110	(a)	8	8	50	35	29	54.6
110	(a)	3	1	75	149	0	100
110	½	2	1	66.6	217	0	100
110	½	5	5	50	7	77	8.3
110	1	18	0	100	127	0	100
110	1	3	3	50	24	0	100
110	1	15	4	78.9	121	0	100
110	1½	10	0	100	88	0	100
110	1½	10	13	43.4	55	23	70.5
110	2	14	2	87.5	475	0	100
110	4	82	0	100	105	0	100
110	4	14	0	100	36	0	100
110	5	18	0	100	93	0	100

(*a*) = Until the indicated temperature was reached.

TABLE 2. MORTALITY OF LARVAE OF *Merodon equestris* AND *Eumerus* SPP., RESPECTIVELY, IN NARCISSUS BULBS TREATED WITH VAPOR HEAT; TESTS IN 1931

Temperature °F.	Duration of treatment Hours	Condition of larvae Dead Number	Alive Number	Mortality Per cent
		Merodon equestris		
110	2	12	0	100
111	2	16	0	100
112	2	14	0	100
113	2	15	0	100
114	2	11	0	100
115	2	21	0	100
		Eumerus spp.		
111	½	450	2	99.5
111	¾	232	2	99.1
111	1	251	0	100
111	1¼	202	0	100
111	1½	352	0	100
Check	–	19	309	6.1
110	4	823	0	100
Check	–	0	442	0

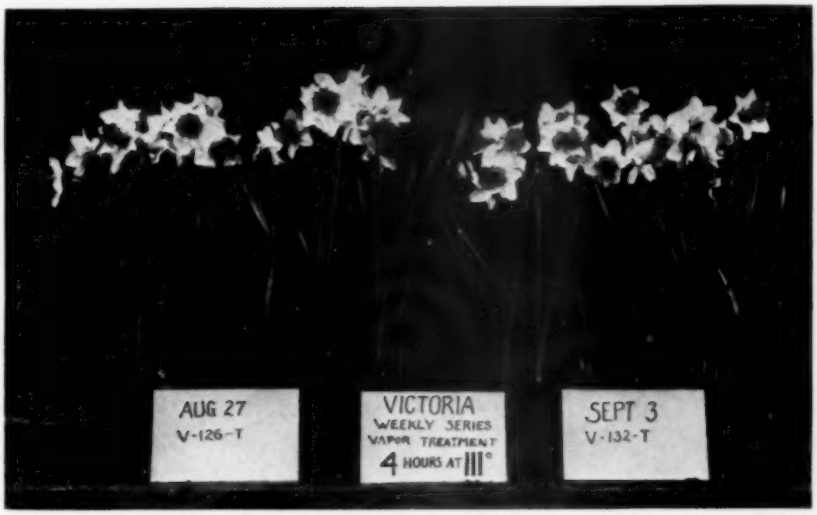
EFFECT OF TREATMENT ON NARCISSUS BULBS. Extensive experiments have been made to determine the tolerance of the bulbs to the vapor-heat treatments. These tests have been divided into two general classes: (1) Those on a commercial scale, using between 8 and 14 tons of planting stock per load, to ascertain the behavior of the treating equipment with capacity loads, which would reduce the evidence of individual variation found in small samples; and (2) experimental lots, usually of 75 bulbs each, where the temperatures and the time could be regulated very closely.

A four-hour period was used for all the commercial-scale treatments, this period being calculated *after* the temperature in the bulbs in all parts of the treating room had reached 111° F. Loading to capacity necessarily caused an uneven result, because the top trays would heat more rapidly than those underneath. As the period of preheating ranged from 4 to 6 hours, a total of from 8 to 10 hours was required for completion of the treatment. At the end of the treating period heat and water were shut off, the vents and the door were opened, and the fan was allowed to run for 12 hours (usually overnight). When the bulbs were subsequently removed they were completely dry, and were placed under conditions of commercial storage without detrimental after-effects. It was found that in instances where bulbs were removed without this cooling period, the condensed moisture on the bulbs caused them to mold when in storage. Treatment of bulbs in shipping cases was found to be conducive to irregularities in bringing a load up evenly to the desired temperature; consequently the use of shallow trays is considered advisable.

In the commercial treatments the results were of course variable, owing to the foregoing conditions. No marked effects were noted in the field growth. An occasional slight spotting of the leaf tips was considered to be due to the longer treatment received by the upper trays. Where bulbs had been treated rather late in the dormant season, blind flower buds appeared, but growers do not consider these to be detrimental to planting stock. In practically all cases the growth was judged to be more vigorous and the weight increase greater than in the case of untreated stock.

In the season of 1930, 160 tons and in 1931 more than 700 tons of planting stock were treated under supervision of the laboratory staff. Ninety-three varieties of narcissus were included in these treatments.

FORCING RESULTS. An important feature of the vapor-heat treatment is its effect on bulbs intended to be forced in greenhouses. During the



Samples of forced Victoria narcissus showing vapor-heat-treated bulbs in comparison with untreated ones. The samples chosen are from the "weekly treatment series" of Victoria. Above, two "check" flats; below, vapor-heat-treated bulbs, treated August 27 and September 3, respectively, for four hours at 111° F. Photographed February 18, 1932.

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past season several experimental series of bulbs were forced at the laboratory greenhouse. The results are considered favorable, as the following data will show.

Effect of season of treatment. Samples of certain lots of bulbs were treated for four hours at 111° F. at weekly intervals throughout the dormant season, starting the day after digging and continuing to October 1, to determine the effect of season of treatment. Three varieties were used—Victoria (Plate 33), King Alfred, and *Poeticus ornatus*—all samples of which received uniform handling throughout, the date of treatment being the only variable factor. In all three varieties the treatments between the first of August and the middle of September gave normal flowers. Early treatments caused slightly inferior flowers, while the late treatments produced blind flower buds. The foliage was normal in all samples.

Effect of length of treatment. Samples of Victoria bulbs were treated a 111° F. for 4, 6, 8, 10, and 12 hours late in August, an optimum time in the season, as indicated above. Excellent flowers were obtained after all treatments. The blooms appeared in reverse order of the length of treatments, those receiving the 12-hour treatment blooming first and the check last.

Effect of temperature. Samples of the varieties Victoria and Emperor were treated for four-hour periods at temperatures ranging from 110° to 115° F. in one-degree intervals. In each variety a definite dwarfing occurred in samples treated at 113° F. or above. There was no apparent difference in the quality of the flowers between the samples treated at 110°, 111°, and 112° F., and these were about equal to the check. All treatments produced flowers, but those treated at 113°, 114°, and 115° F. were of poorer quality than the others.

CONCLUSION. From the foregoing discussion it is indicated that the vapor-heat method is adaptable for the treatment of narcissus bulbs. A two-hour treating period at 111° F. is indicated as the minimum requirement for satisfactory insecticidal results. Treated bulbs may be successfully forced provided that the treating is done within the optimum period. Although in one series long-time periods produced good flowers, it is considered better to control the maximum period more definintely than was done in the commercial loads. It is expected that this point will be clarified in this season's work. The treatment in general benefits planting stock by causing more vigorous growth and added increase in weight.

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Dicerca divaricata as a Defoliator. June 23, 1932, at L'Anse, Michigan, my attention was called to numbers of freshly fallen maple leaves, otherwise uninjured upon the ground. Examination disclosed these leaves similar to leaves collected many times in other places, i.e., dropping of the leaves was caused, not by the formation of an abscission layer but by severance of the petiole by some chewing insect. The defoliation of the small trees under observation was almost complete and in this case undoubtedly put the trees in very poor condition. The only insect present in numbers upon the trees, was *Dicerca divaricata*. Some three dozen of these insects were collected and caged with leafy maple branches.

The insects cut the leaves from the branches by severing the petioles. Several replications were made with the same result.

The possibility of poisoning the beetles with an arsenical applied as a spray to the foliage with negative results.

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BORDER PLANTINGS AS GUARD ROWS IN PINEAPPLE MEALY BUG CONTROL[1]

By WALTER CARTER

ABSTRACT

The planting of several beds of pineapple plants in a strip parallel to the edge of fields and separated from the main plantation by a road is proving essential to economical spraying against *Pseudococcus brevipes* Ckl. These borders serve as guard rows against too rapid a movement of mealy bugs into the field and at the same time localize the area to be regularly sprayed.

Pineapple fields generally become infested with *Pseudococcus brevipes* (Ckl.) as a result of movement of the insects from the roots of grasses and other plants which grow along field margins (1). The accumulation of mealy bug populations on the pineapple plants growing on the edges of fields contiguous to these grasses and their gradual movement into the field area have been shown to be definitely responsible for a serious wilt disease of pineapples (4, 2), which was known as "edge wilt" long before its connection with mealy bugs was understood.

The slower movement occurring when the pineapple beds were planted parallel to the grassy margin suggested some modifications of plantation practice which have proved of great value in mealy bug control. Hence the name "guard rows."

THE BORDER PLANTING. The ordinary practice in plantation planting was to plant on contour, running the beds parallel at right angles, or obliquely to the field margin as convenience dictated. This practice was modified first to the extent of planting a narrow strip parallel to the margin, and separated from the main field by a plantation road. At this time no data were available on spray controls, and borders were considered only as a means of slowing up mealy bug movement. Density of planting and width of border were determined by local circumstances and in the first experimental borders these two factors varied considerably. Counts of mealy bug populations on these borders showed, however, that they were accomplishing a useful purpose. Their usefulness was found to be conditioned by their width and the condition of the plants in the border, compared with that of the plants in the main field. Where the border planting had been made on extra land taken into the field area for the purpose and without adequate preparation, the plants were sometimes tough and stunted. Sometimes the width of the border would be

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reduced, because of the irregularity of the field margin, to 3 or 4 feet. Movement of mealy bugs into the plantation area occurred at these places. From these initial experiments it was concluded that border plantings must be of considerable width, and be grown under the same agronomic conditions as the main plantation. A minimum of four 2-line beds or three 4-line beds, totaling 8 or 12 rows, was set arbitrarily. This involves approximately 25 feet of width.

With the development of spray controls (3) the use of border plantings became of much more significance. Instead of merely delaying the movement of the mealy bugs into the field, the border plantings served to localize infestation to a very small percentage of the total area of the field, which could be sprayed regularly at a relatively very low cost. At the same time, possibilities of overflow of mealy bugs from the border planting into the main field could be obviated. Some details of an experiment in mealy bug control which included a border planting are presented, since quantitative data from this are available.

Populations of Mealy Bugs Occurring in Sprayed and Unsprayed Border Plantings. This border planting met the requirements of width and agronomic conditions. It ran for a distance of approximately 3200 feet and both the border and the plantation blocks contiguous to it were included in the experiment, which was undertaken to determine frequency of border spraying necessary to protect the main plantation. Samples were taken from time to time to determine the mealy bug populations and their distribution. The first of these, taken December 3, 1930, approximately 3 months after the plots were planted, and prior to the first spraying, showed small and very much scattered infestations established on the outer margins of the border. In March 1931 all the sprayed portions of the border were free of mealy bugs as well as one check plot (A). The other check (B), showed 5 plants out of 36 infested with populations up to 25 mealy bugs per plant.

In June 1931 the plantation blocks were gone over carefully in addition to the regular samples on the border planting. This sample revealed the fact that only the border plantings which had not been sprayed were infested, and that none of the contiguous plantation blocks showed infestation, even those opposite the infested check borders.

In October 1931, the plots were again sampled. At this time two types of sampling were used in the border planting. In one, the regular method of pulling plants was used: in the other, each plant was examined carefully for mealy bugs and a record made of the number of plants on which the insect was to be seen. Each method has its usefulness and its

Plate 34

Aerial photograph showing layout of border planting experiment. White dots represent plants infested with mealy bugs. (Photo by 11th Photo Section A. C., Luke Field, Oahu, T. H.)

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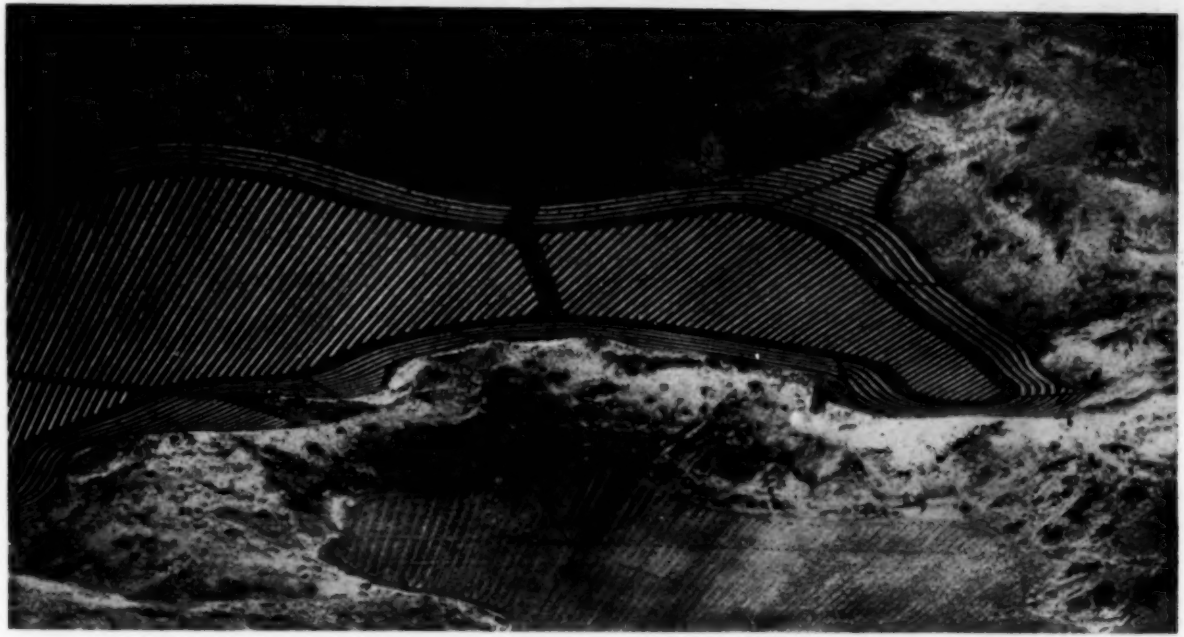

Aerial photograph of newly planted field showing arrangement of border guard rows. (Photo by 11th Photo Section A. C., Luke Field, Oahu, T. H.)

drawbacks. When the plants are pulled and dissected, the mealy bug count is absolute. The number of plants that can be treated in this way is relatively very small. The inspection method includes a very much larger number of plants but misses some very low infestations. This last method records the extent of infestation but not the size of individual infestations. It was necessary to use the inspection method only, on the main plantation blocks in this last count, in view of the large area involved. The data of these samples are shown in Table 1.

TABLE 1. MEALY BUG POPULATIONS ON SPRAYED AND UNSPRAYED BORDER PLANTINGS AS SHOWN BY ACTUAL COUNT AND INSPECTION METHOD OF SAMPLING

	Populations determined by actual count of mealy bugs present			Infestation determined by inspection		
	No. of plants in sample	Percentage of plants infested	Average population on infested plants	No. of plants in sample	No. of plants infested	Percentage of plants infested
Plot 1.....	16	50	9.2	1,430	248	17.34
Check A...	12	66.6	47	877	619	70.58
Plot 2.....	12	0	0	614	4	0.65
Plot 3.....	20	5	1	1,630	51	3.13
Plot 4.....	12	16.6	1	645	6	0.93
Check B...	8	100	66.3	545	524	96.14
Plot 5.....	8	0	0	674	5	0.74
Plot 6.....	12	8.3	246*	800	22	2.75

*Single plant infested.

Plate 34 is an aerial photograph of a portion (plots 3 to 6 inclusive) of this experimental field. The points of infestation have been marked on the print. It will be seen that except for a few scattered infestations remote from the border plantings, infestation in the plantation blocks is limited to the edge of plot 4. This plot is bounded by check B, which was almost 100% infested. The overflow from this check plot evidently infested plot 4, via a drainage ditch which passes between the two plots. Infestations in the border portions of the sprayed plots are quite evidently reinfestations from the margins, which have not reached the inner edge of the border. As shown in Table 1, the size of these infestations is much smaller than in the checks. The figure summarizes the data on the guarding effect of border plantings. The heavy infestation in unsprayed borders and the overflow from these into the main plantation after a period of approximately one year, are clearly evident. The relative cleanliness of sprayed borders and the localizing of reinfestation on the outer lines of the borders, illustrates what is now occurring as plantation practice throughout most of the pineapple areas in the Hawaiian Islands. The scattered infestations seen at a distance from the border are,

no doubt, the result of planting infested planting material and the rarity of these is indicative of the relative importance of such infestations compared with those originating as edge infestations.

The spraying of guard row borders is eliminating the major source of field infestation of mealy bugs, and its cost when applied on a per acre basis over the whole area protected, amounts to less than 75 cents per acre per application, even in those areas where the ratio of periphery to area is high. Such a field is shown in Plate 35. This field had a border planting over 3 miles in length for a field area of 135 acres. The facility with which border plantings can be sprayed and the repeated proofs of their efficacy encountered by plantation men under practical field conditions, have led to the planting of wider and more uniform borders. Plate 36 shows the spraying of a 5-bed border on the island of Kauai.

It occasionally happens that mealy bugs pass through a barrier planting by way of drainage ditches, and infest the edge of the plantation proper. This involves spraying a strip round the main plantation, using the road between border and plantation for the spraying machinery to pass. The extent of this additional spraying is much reduced, however, by the employment of survey crews who ascertain the area involved. Spraying is then limited to that area.

CONCLUSION. Border plantings made as a result of a study of mealy bug movements, were first planted to slow up the movement of mealy bugs into pineapple plantations. With the development of adequate spray methods these borders were used to guard the plantation from mealy bug infestation by regularly spraying the borders, thus eliminating the mealy bugs as they first entered the field. The practice has been found essential to the economical and practical control of mealy bugs and is now standard practice.

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Plate 36

Spraying 5-bed border on Island of Kauai

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COMPARISON OF TOBACCO DUST WITH OTHER FORMS OF NICOTINE IN CONTROL OF YELLOW SPOT DISEASE OF PINEAPPLES[1]

By WALTER CARTER

ABSTRACT

Tobacco dust was tested along with seven other nicotine forms as a control measure against yellow spot. The distribution of plots in the experiment was such as to offset the irregular incidence of yellow spot which naturally occurs. The results of this experiment clearly indicate the superiority of tobacco dust over the other nicotine applications. Incidence of the disease was conditioned by growth and succulence of the plant, the infestation being lower in the poorly growing areas of the field. The reduced infestation in tobacco dusted plots is believed due to the changes induced in the plant as a result of the dust application: Agronomic variations between areas may offset or accentuate this effect.

A virus disease of pineapples known as yellow spot has been recently described (1, 2). The vector is *Thrips tabaci* Lind. and early attempts at control were directed at preventing access of the insect to the soft heart tissue of the plant. Various materials were thrown into the heart of the plant to serve as mechanical plugs against the entry of the insect. One of these was tobacco dust. Experiments with this material had been performed on a practical plantation basis and the results had led to the adoption of tobacco dusting as a regular plantation practice. On the other hand the data appeared to require independent checking up in view of the fact that the experiments on which the conclusion mentioned above was based, while satisfactory from the plantation viewpoint, were not of a type as would justify the Experiment Station making any general recommendation as to the value of tobacco dust in yellow spot control. The size of the insect vector, *T. tabaci*, the interval between dustings, and the tendency of the dust to lose any capacity to plug the heart leaves of the plant against invasion, led to a doubt as to the validity of the explanation that tobacco dust acted as a mechanical repellent. Two other hypotheses were possible, one that nicotine was absorbed and prevented either the insects feeding or the development of the virus in the plant; the other that the retardation of growth following tobacco dust applications reduced to the plant's susceptibility to the virus.

An extensive field experiment was arranged in Hawaiian Pineapple

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Co. Field 3-D, Kipapa, Oahu, in which seven other forms of nicotine and nicotine combinations were checked against tobacco dust as yellow spot controls. Since tobacco dust application was the standard practice on that plantation no untreated plots were set up, the wide variation in the other materials offering a fair opportunity for variation in results.

TABLE 1. DISTRIBUTION OF YELLOW SPOT ACCORDING TO PLOT.
Figures represent total number of plants infested in each plot.

C 47	E 64	B 65	A 78	D 64	H 105	G 57	F 158
E 49	C 64	A 62	B 74	H 62	D 163	F 190	G 93
B 84	A 123	C 67	E 94	G 31	F 116	D 245	H 198
A 80	B 104	E 67	C 87	F 71	G 42	H 298	D 205
D 56	H 99	G 21	F 65	C 62	E 103	B 203	A 217
H 80	D 133	F 83	G 27	E 78	C 122	A 227	B 246
G 25	F 141	D 127	H 84	B 73	A 163	C 204	E 270
F 70	G 43	H 85	D 91	A 79	B 135	E 200	C 295

The arrangement of the plots was of some significance. Previous experiments on yellow spot control carried on throughout the summer of 1930 were not of a type as would permit systematic arrangement to offset irregular infestation. Since the blocks in 3-D were regular and on an even gradient, 8 acres were divided into 64 1/8-acre plots which were arranged as shown in Table 1. It will be observed that the distribution of plots provide for each line in each direction to have one and only one treatment of a kind, in it. The arrangement departed from the formal Latin Square arrangement in that diagonal arrangement of similar plots was permitted; in the event of soil heterogeneity existing along these diagonals such an arrangement would have been undesirable.

The list of materials used is given below:

A. Nico-fume	This material is nicotine in the alkaloidal form. Applied at the rate of 35 cc. nico-fume to 3 gals. water.
B. Nico-fume in Penetrol	As in plot A with the addition of an oil which is reputed to increase the activity of the nicotine. 60 cc. Penetrol and 35 cc. nico-fume to 6 gals. water.
C. Black Leaf 40	The standard nicotine-sulphate compound applied at the rate of 10.8 cc. to 3 gals. water.
D. Black Leaf 40 in Penetrol	As in plot C with the addition of the activator. Applied at the rate of 10.8 cc. B. L. 40 and 30 cc. Penetrol to 3 gals. water.
E. Petrotine 60 and Nico-fume	Addition of nicotine to oil emulsion is reputed to increase the efficiency of the oil. In this case the combination was used in an empirical way to provide a nicotine application in an oil carrier. Used at the rate of 35 cc. nico-fume to 6 gals. of 1% Petrotine.
F. Petrotine 60 and Black Leaf 40	As in plot E as far as the oil was concerned. Applied at the rate of 10.8 cc. B. L. 40 to 3 gals. 1% Petrotine.
G. Tobacco Dust 1.2%	Applied with a shaker device into the hearts of the plants.
H. Nico-dust	A lime-impregnated nicotine dust; applied as was the tobacco dust.

Materials were applied on the following dates:

10/17/30	1/21/31
10/31/30	2/18/31
12/ 2/30	3/ 7/31
12/31/30	4/14/31

Approximately 50 gallons of the liquid sprays were used to the acre; of the dusts approximately 60 lbs. of tobacco dust and 60 lbs. Nico-dust per acre were applied.

As these materials are generally used for insecticidal purposes, the dust applications represented fair "doses" as contact poisons; of the sprays the strengths used represent fair insecticidal strengths against soft bodied insects, but the volume used would probably be considered small. These materials were applied, not primarily as insecticides, since it was recognized that no contact insecticide would avail against so transient and casual a visitor to pineapple plants as is *T. tabaci*, but on the hypothesis that the application of nicotine prevented the development of yellow spot.

Each time a count was made all the yellow spotted plants over the entire area were pulled out, counted, and removed. All doubtful cases were left until the succeeding count in order to avoid error. These data are presented in a somewhat summarized form in Tables 1 and 2.

TABLE 2. SUMMARY OF YELLOW SPOT COUNTS ACCORDING TO MATERIAL USED

Material	Total yellow spotted plants removed						
	12 1/30	12 23/30	1 17/31	3 7/31	4 10/31	6 2-3/31	Total
A. Free Nicotine	52	61	146	410	218	142	1,029
B. Free Nicotine+Penetrol	60	63	148	426	179	108	984
C. Black Leaf 40	59	75	160	367	190	97	948
D. Black Leaf 40+Penetrol	43	75	183	463	190	130	1,084
E. Petrotine 60+Free Nicotine	47	39	171	388	166	114	925
F. Petrotine 60+Black Leaf 40	32	50	156	365	153	138	894
G. Tobacco Dust	12	10	28	130	70	89	339
H. Nico Dust	21	39	143	423	238	147	1,011
Grand total							7,214

DISCUSSION. Table 1, in which the counts are shown by plots, gives an interesting picture of distribution of the disease. It will be observed that the heaviest infestation occurred in a strip bounded on one end by the plantation road and at the other by the upper end of the plot next to the gulch. The infestation was heaviest at the plantation road end and decreased as the gulch was approached. This zone of highest infestation closely approximates the area in which growth was normal. On one side of the area and particularly the upper portion, growth was subnormal with an extremely heavy infestation of root knot nematode. There appears to be a definite relationship between normal succulent growth and susceptibility and this relationship probably accounts for the results obtained with tobacco dust. The application of tobacco dust to very young plants retards and toughens the plant and without data on the physiology of the plant with respect to the virus of yellow spot, it would seem that this retardation of growth is primarily responsible for the control achieved by tobacco dust applications.

The lack of results from the use of nico-dust does not necessarily alter this conclusion. At the close of the experiment the plots treated with nico-dust were extremely chlorotic but only slightly retarded and in the early stages of growth this was not observable.

Table 2 which gives the total for each count and for the season, for each material indicates that none of the other materials used had any noticeable effect. This is supported by the fact that until the last count was made, the ratio between counts on tobacco dust and on the other material was maintained, as well as by the close similarity in infestation observed between all the other materials. Should the other materials used have had some effect, however, then the advantage of tobacco dust over no treatment would be even more pronounced.

If the conclusion previously expressed is valid, however, that the effect of tobacco dust was through a conditioning of the plant, then it

must be remembered that a good many other factors might retard plant growth in the early stages with a similar effect on susceptibility. It is therefore possible that agronomic differences between localities would be sufficient to offset the effect of tobacco dust.

The last count taken 6/2/31 indicates that with increasing age and growth the relative effect of tobacco dust was much lessened. This confirms plantation experience along the same lines.

The economics of the treatment are primarily for plantation authorities to determine. Essentially the problem is one of applying an insurance measure over large areas in order to protect the stand in very much smaller areas.

The real significance of this confirmation of the effect of tobacco dust lies in the fact that the plant can possibly be conditioned to reduce its susceptibility to disease. This is fundamental and opens up a field of investigation which is worthy of effort in connection with all the plant parasites with which we have to deal.

SUMMARY. Tobacco dust was tested along with seven other nicotine forms as a control measure against yellow spot. The distribution of plots in the experiment was such as to offset the irregular incidence of yellow spot which naturally occurs. The results of this experiment clearly indicate the superiority of tobacco dust over the other nicotine applications. Incidence of the disease was conditioned by growth and succulence of the plant, the infestation being lower in the poorly growing areas of the field. The reduced infestation in tobacco dusted plots is believed due to the changes induced in the plant as a result of the dust application: Agronomic variations between areas may offset or accentuate this effect.

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SOME EFFECTS OF REDUCED ATMOSPHERIC PRESSURE UPON HONEY BEE RESPIRATION

By CHARLES E. WOODWORTH, *Formerly Assistant in Economic Entomology, University of Wisconsin*[1]

ABSTRACT

The respiration of the honey bee is very markedly affected by changes in atmospheric pressure. Over a fairly wide range, however, they can internally compensate for these changes.

To the present time very little work has been done on the physiological effect of reduced pressure, or altitude, upon insect life. There has been no attempt, as far as the writer can discover, to determine definite quantitative measures of the effect of reduced pressure in the study of insect metabolism. Pressure further has been neglected, or set aside, with the remark that the effects are so slight that it need not be considered. Chapman (1931) states, however, "We are not surprised that animals should be affected by changes in pressure."

Of all the methods at hand for determining the nature of the body metabolism, the study of respiration undoubtedly gives us the best indications. Since carbon dioxide is produced in all tissue activity, there is thus made available a means of observing the extent of metabolic activity. In spite of the fact that there is little evidence of where, or by what tissue, the activity is taking place, the total metabolism is clearly measurable by this end product.

HISTORICAL SKETCH. Respirational studies have long been a favorite line of attack for insect physiological studies. As early as 1670, just 20 years after the vacuum pump was discovered, Sir Robert Boyle (1670), of the Royal Society of London, did quite an extensive series of experiments on reduced pressure effects on insects. This was a little over a hundred years before the discovery of oxygen, and about 180 years before the discovery of carbon dioxide. It was natural that early workers did no quantitative work on respiration, but it is surprising that so little exact work has been done on insects even to the present date, especially as so much work has been done on man.

Only since 1814 has there been any basis for quantitative work, for it was at that time that Lavoisier and his assistant, Sequin, (1814) set the foundations for chemical physiology. Through their brilliant experiments they were able to postulate that "life is a chemical action". John

[1]Grateful acknowledgment is hereby made to Professor H. F. Wilson under whose direction this work was done.

Mayo (1674) had postulated some 150 years earlier that respiration was analogous to combustion, but unfortunately the work was done so long before the world was ready for it that it was lost, and not again revived until quite recently.

Francois Huber (1814), in the same year that Lavoisier's results were published, proved, in his classic experiments on bees, that air was necessary for life, although they could stand very low air pressures. He also proved that carbon dioxide was produced by the bees.

Since 1814 respiration has been studied by many people, but insects have not been the subject of much work, and the pressure effect has been practically ignored. Paul Bert (1873) published a monumental work on the effect of both increased and reduced pressure on animals, but insects were hardly mentioned. Insects have been mentioned as being affected by pressure change by Herrera and Lope (1899), who worked on aquatic insects of the Mexican Plateau, and by Parman (1920), who observed flies in Texas when they were affected by a tropical cyclone. Both of these merely said that pressure changes do apparently affect insects. Roller (1906) did definitely study quantitatively the effect of increased pressure on the grasshopper, and found that 250 pounds pressure per square inch was necessary to stop breathing. Aside from pressure, many authors have considered various factors that influence respiration and metabolism in general.

In apparently anaerobic conditions, or in atmospheres of pure nitrogen, Davis and Slater (1926) and Bodine (1928) found that insects are able to develop an oxygen debt which is repaid on a return to the normal condition. The latter noted a change in pH associated with this debt. Fink (1925) also noted this debt in hibernating insects. Back and Cotton (1925) found that insects' eggs could withstand almost a complete vacuum.

A few people have worked on the effect of varied oxygen tensions on insects. The effect of this is somewhat the same as that of varied atmospheric pressure, but it lacks the compression factor. Hiestand (1931), Gaarder (1918) and Thunberg (1905) all worked on reduced oxygen tension on insects. The first worked on dragon fly and caddis fly larvae, and the other two worked on the "meal worm" larva. All of these workers showed that reduced oxygen tensions over wide ranges did not affect the rate of respiration. At very low tensions, however, the rate of respiration decreased.

METHOD AND PROCEDURE. For the study being here reported the honey bee was chosen as a subject because of its ready availability throughout

the winter months, and because of the constancy of metabolic age of these individuals from the time of the beginning of wintering to the hatching of the spring brood, a period of several months. With the selection of this apparently "perfect subject", several very interesting complications were met that had to be overcome, or evaluated, before the series of experiments could be conducted.

Besides the ordinary factors that had to be controlled, three interesting and peculiar factors appeared. In the first place, a high degree of irritability was manifested upon the approach of the observer within view of the bees in captivity. This was controlled, along with varying light intensity, by covering the chamber so no light was admitted. Secondly, all irregular vibrations transmitted to the cage had a very marked effect upon the bees. All but the larger ones, such as slamming the door, or hitting the table, etc., were readily eliminated by placing the cabinet and table upon which the cabinet rested, on pieces of sponge rubber. The third idiosyncrasy was the semi-homothermal condition of bees. This was manifested, as will be discussed later, in an attempt to maintain a so-called "thermal zone of comfort". This factor could not be controlled, so had to be evaluated.

The apparatus used for the study was, in principle, a modification of the Haldane (1892) open circuit respirometer. In 1915 Truog (1915) and later Heck (1929) improved the absorber tubes and titrimetric technique. The absorbers were again improved for this study, and will be reported in detail at a later date. They are, however, quite similar to those of Heck.

The technique of handling the apparatus was such that half hour readings were readily made during the experiments. Changes of pressure, to and from that of normal atmospheric, were easily accomplished without the opportunity of carbon dioxide being admitted. Titrations were rapid and the phenolphthalein end-point sharp and definite. The solutions used for titrations and absorption were n/10 and n/50 of both HCl and NaOH. The point used as the critical-point of the experiments was the lowest amount of carbon dioxide obtained under each condition. That was considered to approximate very closely the basal, or better, standard metabolism.

All readings were made at night as there was quickly noted a diurnal variation, the low point of which was late at night. This irregularity was finally assumed to be due to vibrations and disturbances accompanying the daytime activity of man. As mentioned before, major vibrations were transmitted to the bees with the result that abnormally high readings

were obtained. The experimentation was all done in the second story of the entomological laboratory at the University of Wisconsin. This laboratory was housed in a frame building, close to railroad tracks and paved roads. The passage of trains or trucks made noticeable vibrations, the former sufficiently strong to be recorded on the thermographs.

In brief, the method used was to pass humidified, carbon dioxide free air over the bees in the reaction chamber, and then absorb the respired carbon dioxide by means of standardized sodium hydroxide. The carbon dioxide was then precipitated by an excess of normal barium chloride. The unused sodium hydroxide was titrated against standardized hydrochloric acid. By simple calculation it was found that 1 cc of n/50 sodium hydroxide was used up by 0.44 milligrams of carbon dioxide. This figure multiplied by the quantity of sodium hydroxide used up divided by the number of insects in the experiment gave the milligrams per bee per time of exposure, which was readily converted to milligrams per bee per hour. This final figure was found to be within ± 3 per cent, of grams per kilo per hour, which is a very close approximation.

EXPERIMENTAL. With the discussion just completed it seems that a summary of results would suffice to give all the information desired. In addition to this an example is included of the series of readings taken to obtain the summary. In Table 1, that of 50 millimeters pressure, one

TABLE 1. EXAMPLE OF SERIES OF READINGS TO OBTAIN STANDARD METABOLISM

Pressure—50 mm Hg
Temperature—25°C
Number of Bees—50
Bees in cage 6:00 P.M.

Starting time	cc NaOH Used up	Normality	mg CO_2 per bee per hour
1:50 P.M.	7.2	n/50	.1267
10:25 P.M.	4.3	n/50	.0757
11:00 P.M.	3.7	n/50	.0651
11:35 P.M.	3.7	n/50	.0651
12:10 A.M.	2.7	n/50	.0475*
12:45 A.M.	2.7	n/50	.0475*
1:20 A.M.	2.7	n/50	.0475*

* = Standard metabolism.

will note that at 6:00 P. M. 50 bees were put in the respiration chamber and brought to 50 millimeters pressure. At 9:50 P. M. the absorbers were shunted into the exhaust circuit and after 30 minutes exposure were shunted out. Five minutes later new absorbers were shunted in and also allowed to run 30 minutes. This was continued until the experiment was completed. Upon titration there was found that 7.2 cc of n/50 NaOH had been used up in the first run. That means that CO_2, at the rate of 6.336 milligrams was being produced per hour. Dividing

this by 50, or the number of insects used, .1267 milligrams was produced per bee per hour. Similarly 2.7 cc, the amount found in the last 3 readings taken showed that .0475 milligrams was produced per bee per hour. This being the lowest figure, was taken to be the standard metabolism for this condition.

In like manner the carbon dioxide production for several other pressures was obtained and are to be found in Table 2. This information is shown graphically in Figure 66. The relative humidity was 75 per cent

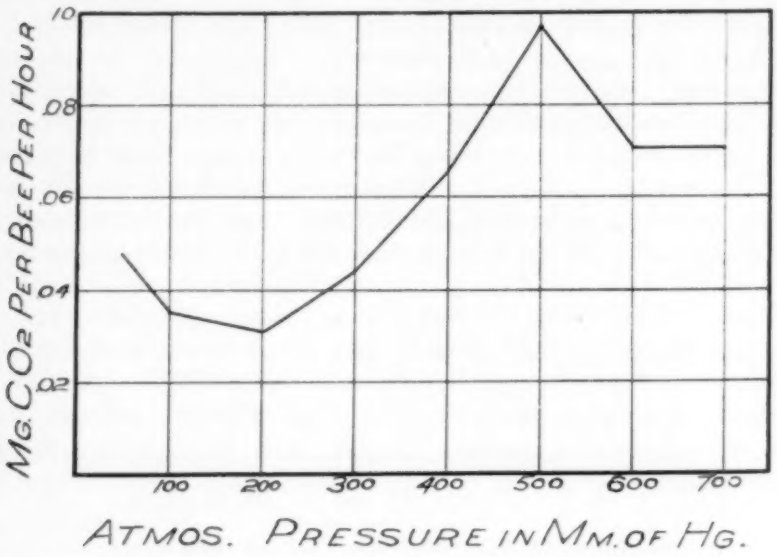

Fig. 66.—Graph showing the effect of various reduced atmospheric pressures upon the standard metabolism of the honey bee. 25° centigrade.

throughout the experiment as that was found to be the average condition from April to November in southern Wisconsin where the work was done.

TABLE 2. STANDARD METABOLISM OF BEES AT 25° C FOR VARIOUS PRESSURES

Pressure in mm of Hg	mg CO_2 per bee per hour	Pressure in mm of Hg.	mg CO_2 per bee per hour
700	.0704	300	.0440
600	.0704	200	.0308
500	.0968	100	.0352
400	.0654	50	.0475

It will be noted that the same metabolic rate is found at both the 600 and 700 millimeter pressure. At 500 millimeters the rate is considerably

higher. At 400, 300 and 200 millimeters the point is respectively lower in logarithmic sequence. From that point on the rate increases at such a rate as to indicate 155 millimeters as the probable low point. This should have a metabolic rate of .0257. This number is obtained by plotting the above figures on semilogarithmic paper. On that paper the curve of the graph of Figure 66 straightens out to straight lines indicating that this is a true biological curve.

At the 500 millimeter point as just mentioned it will be noted that the amount of carbon dioxide is quite a little higher than the amount produced at 600 and 700 millimeters. At first this seems to be an error, but on closer examination it is seen to be correct. If one will recall the temperature responses of bees, one will remember that at lower temperatures than normal there is an internal compensation or muscular activity to raise the temperature back to normal. This fact is very interestingly reported by Wilson and Milum (1927) in their bulletin on "Winter Protection for the Honey Bee Colony." With that in mind it seems probable that from 700 millimeter to 600 millimeter pressure there is no marked internal tension sufficient to cause irritation. At 500 millimeters, however, the lowered pressure is sufficient to cause a similar response to that of lowered temperatures.

Since the 400 millimeter, 300 millimeter and 200 millimeter pressures produced a regular logarithmic curve, it seems that at all of these points irritation activity takes place but in a proportionately lower plane due to reduced oxygen tension. This apparently continues to a point where stupefaction begins to take place. At 100 millimeters considerable stupefaction has taken place so the irritation activity reduces its vigor. At 50 millimeters stupefaction goes on more completely and, therefore, respiration is less labored and becomes almost exactly that caused by reduced temperature only. This seems to be more or less in accord with the studies on reduced oxygen tension but is complicated by the addition of the compression factor.

SUMMARY. The above discussion can be simply expressed as follows: Bees are affected by reduction in pressure. Over a very wide range no noticeable effect is present. Below that point irritation activity is experienced. The strength of this activity is reduced quantitatively with reduction of pressure until stupefaction interferes. There is then a return to the respiration rate which we have obtained under normal pressure, but at such a temperature that activity appears to be reduced to a minimum.

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PREDICTION OF PALE WESTERN CUTWORM INCREASE IN MONTANA IS FULFILLED

By R. E. WALL,[1] *Montana Agricultural Exp. Station*

ABSTRACT

The first general outbreak of the pale western cutworm in eleven years occurred in 1932, verifying the prediction made a season in advance. Damage to approximately 140,000 acres of grain was recorded in twenty-six counties. It is expected that an analysis of the new data on the relation of weather to increase and decrease in cutworm abundance in 1931, 1932, and 1933 will permit of further refining of the forecasting method.

A general outbreak of the pale western cutworm (*Agrotis orthogonia* Morr.) occurred in Montana in 1932 for the first time in eleven years. Damage to approximately 140,000 acres of grain has been recorded in twenty-six central and eastern Montana counties (see Figure 67), and

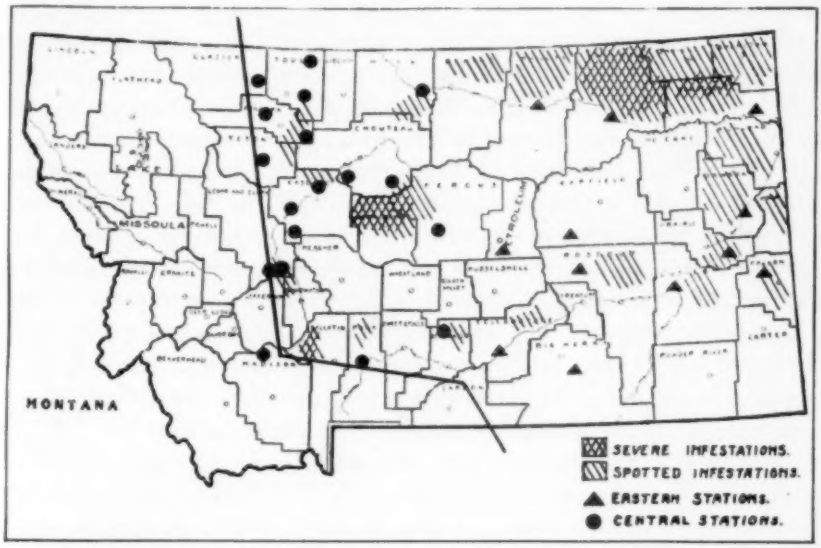

Fig. 67.—Pale western cutworm (*Agrotis orthogonia*) outbreak areas in 1932 and stations from which precipitation records were taken.

small acreages of corn and garden crops have also been damaged. It is estimated that the loss on the infested grain fields will average thirty per cent despite ideal growing conditions during May and June. Very many fields were totally destroyed and in some instances where the

[1]Contribution from Montana State College, Agricultural Experiment Station. Paper No. 22, Journal Series.

mistake was made of re-seeding a second stand of grain was taken. The destroyed grain included about equal amounts of winter and spring wheat. The extensive and severe infestations of the cutworm are the more remarkable because the species has not been abundant enough to attract noteworthy attention in Montana for a decade.

This outbreak was predicted on the basis of precipitation records of the last two years and it is with great interest that we note the degree to which the prediction is verified. The late J. Arthur Harris, biometrist at the University of Minnesota, has said that the evolution of the science of biology could be outlined in three stages; first, the observational stage, next the experimental stage, and finally the prediction stage. In Entomology this last stage seems to have been arrived at recently in some instances. Noteworthy among these is the case of the pale western cutworm as it occurs in the more arid regions just east of the continental divide.

The economic history of this species is still young but it was soon recognized that the pest followed years when drought was prevalent. In 1923 Mr. H. L. Seamans of the Dominion Entomological Service, pointed out this relationship and stated that for practical purposes more than ten wet days in May and June would materially reduce the number of *A. orthogonia* maturing. The Montana Studies made by Doctor W. C. Cook on weather relations of the species and on probability of outbreaks, should be referred to in considering the development of the prediction method. (Cook 1926, 1928, 1930.) A study of weather data for the years surrounding the three-year (1919–1921) Montana outbreak when arranged in climograph form, pointed to May, June and July precipitation of the preceding years as the governing factor. A nearly linear relationship between total precipitation for this period and resultant change in abundance of the cutworm was indicated by an inspection of tabulated data and the turning point appeared to be four inches. With rainfall totaling less than four inches an increase of *A. orthogonia* was recorded the following season but more than that amount produced a decrease in the cutworm population.

The foregoing prediction value was arrived at on the strength of records from a single series of outbreak years but a complete statistical analysis of the available data gave such high correlation between precipitation for the period in question and change in abundance of the cutworm that it has seemed that reasonable reliance could be placed on the value. Cook calculated the probability of occurrence of such favorable years for cutworm increase in Montana and concluded that slight local outbreaks

might occur every 5 to 10 years in various parts of central and eastern Montana but that severe outbreaks (following pairs of seasons favorable for *A. orthogonia* increase) were due only once in from 16 to 30 years. Two dry seasons are necessary before severe damage can be inflicted because even under favorable conditions it does not appear that the pale western cutworm is capable of more than trebling its population in one year. Since outbreaks of the insect are not experienced frequently, it takes time to acquire data and test out prediction values.

It is to be noted that a forewarning of trouble in the case of the pale western cutworm may be of greater value than in the case of many other insect pests, because no active control measures are effective once the fields are infested. Poison bait is a complete failure since the larvae do not come to the surface and no cultivation methods tried will materially reduce a population once established. Chief dependence is placed upon avoidance of the insect through tillage practices which will discourage the moths from ovipositing on fields which are to be cropped. Clean summer fallow which is neither cultivated nor trodden upon by stock from mid-July until late September will, by the action of showers, present an encrusted surface which is not so liable to receive the eggs of the moth. Growers must be warned of an impending outbreak during the summer preceding the potential spring outbreak.

Figure 68 indicates the general trend of pale western cutworm damage and rainfall records over a period of years. The precipitation histograms give the mean for eighteen central Montana and twelve eastern Montana stations selected because of their *orthogonia* history. The damage indicated in the curves is the per cent damage to all grain over the whole of infested areas and it is to be noted that even with five per cent damage over an area many individual fields will be totally destroyed.

The critical and sub-critical rainfall of 1918 and 1919 was followed by the outbreak of 1919, 1920 and 1921 as shown. From 1922 to 1930 inclusive with precipitation records as indicated, damage from the pale western cutworm was quite negligible. However, the 1930 and 1931 precipitation records point to trouble, as can be seen from the charts.

The 1932 outbreak was predicted last year using the forecasting basis already described. In 1930 the May-July total was below the critical four inch value in practically all sections of central and eastern Montana with the result that spotted infestations became evident in 1931 and a few localities reported important crop damage. Again in 1931 the rainfall was quite deficient during May and June, though in the central part of the State heavy rains during the first few days and the last few days

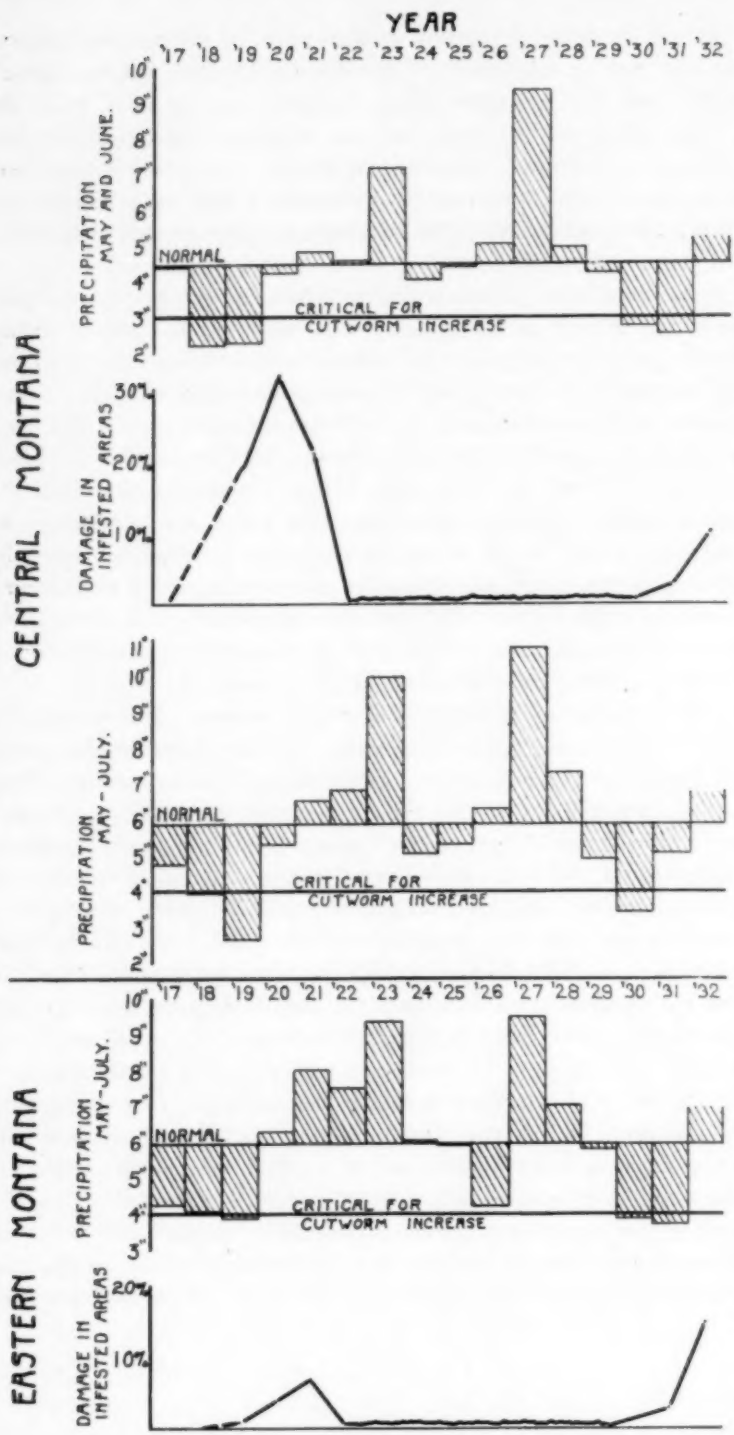
YEAR
'17 '18 '19 '20 '21 '22 '23 '24 '25 '26 '27 '28 '29 '30 '31 '32
CENTRAL MONTANA
PRECIPITATION MAY AND JUNE.
NORMAL
CRITICAL FOR CUTWORM INCREASE
DAMAGE IN INFESTED AREAS
PRECIPITATION MAY-JULY.
EASTERN MONTANA

Fig. 68.—Mean precipitation values in central and eastern Montana over a period of years and damage caused by the pale western cutworm.

of July brought the totals up considerably. Normally about twenty-five per cent of the rain for the three month period falls during July but in 1931 the stations in central Montana registered almost precisely fifty per cent of the total during July. The effect of this abnormal distribution was difficult to evaluate in making predictions. In Figure 68 the precipitation in the case of central Montana is shown above for May and June only in contrast to the three month records shown below.

The action of rainfall in increasing mortality in *A. orthogonia* is not fully understood though evidence has been presented to show that disease and parasitism are higher during seasons when rainfall is abundant. Whether or not these are the sole factors involved is not of great concern so long as prediction based upon precipitation works, though in this instance of abnormal July rainfall careful consideration was given to the mechanism believed to be responsible for reducing the cutworm, and it was concluded that May and June might prove to be a better index.

Reference to Figure 68 will show that the cutworm outbreak is not as bad in central Montana as would have been expected on a basis of the May and June period but that it is possibly worse than the May, June and July total would have indicated. Events have shown that it would have been most accurate to take a period intermediate between the two arbitrary ones considered. This problem did not exist in the eastern Montana region and the damage there exceeds expectancy somewhat, especially in the northeastern quarter.

The local distribution aspect of the outbreak has not been handled for practical reasons though a very real problem of this nature exists. One locality is badly infested while a nearby locality escapes in innumerable instances. The sparse placing of meteorological stations within Montana and the lack of a sufficient force of scientific field workers to study the local distribution during the course of an outbreak are handicaps which make progress in this direction difficult and at best we are only able to gather fragmentary evidence.

In fact those two deficiencies are the greatest drawbacks in our prediction method. The infrequency of outbreaks of this species also makes for slow progress in the development and testing of the prediction method. Much patient waiting is required between outbreaks. Another result of the infrequency of outbreaks is that recommendations for the avoidance of the pest must be made vigorously when trouble is in sight if the wheat farmers are to be moved to action. County Extension Agents and other agricultural workers were given notice of the present trouble and the outlook for 1932 cutworm damage was later published

in the "Montana Farmer" (Wall 1931), but many growers took no notice of this.

In general the prediction of pale western cutworm in 1932 has been amply verified by the present outbreak and the method has shown its worth. It is expected that an analysis of the data on increase and decrease of the cutworm populations during 1931, 1932 and 1933 with reference to precipitation records of the preceding seasons will serve to refine the method still further.

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Note on Cherry Fruit-Fly Oviposition. On June 10th, 1932, the black-bodied cherry fruit-fly, *Rhagoletis fausta*, was observed attempting to oviposit on Montmorency cherries that would mature about July 13th. The fruit, of course, was small, green, and extremely hard. The female fly repeatedly tried in vain to force her ovipositor into the partially grown fruit. After making several attempts to find a desirable spot, during which she covered the entire surface of a small cherry, she flew to the next group and attempted to lay eggs there as before, but it was very apparent that a spot soft enough could not be found. All attempts to deposit her eggs seemed unsuccessful.

It would appear, therefore, that the date of oviposition of the black-bodied cherry fruit-fly may be determined somewhat by the stage of the fruit, and that the date of spraying for this insect may not depend altogether on the emergence of the fly. It would appear that the development and the softening of the fruit before ripening-time exert an influence on the date of oviposition.

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WINTER TEMPERATURE GRADIENTS AS A FACTOR IN INSECT SURVIVAL

By G. ALLEN MAIL[1]

ABSTRACT

Data are presented to show the small fluctuation of soil surface temperatures under a snow covering compared with air temperatures.

An increasing interest is being evidenced in soil temperatures in connection with biological research, and comparatively little data are available. In the Northern United States and Canada, winter soil temperatures, especially in the first twelve inches, are of great significance. The ability of insect eggs to over-winter, or subterranean larvae to hibernate, is ofttimes directly correlated with the temperatures to which these organisms are exposed.

Interesting data were obtained during the past winter at the Montana Agricultural Experiment Station at Bozeman. By means of thermocouples, not only in the soil but extending at inch intervals above the soil, it was possible to get actual figures on the degree of insulation against cold afforded by snow covering. During the past winter, there was an almost constant covering of snow over the instruments from December 1st to March 31st, and the average daily air temperature during this period fluctuated between —25°C. and +8.0°C., a spread of 33°C. For this period the frost line or depth to which the ground was frozen, did not go below 20 inches; the minimum soil surface temperature was only —4.0°C. Under this blanket of snow the frost line showed, due to the snow covering, no relation to air temperatures. No soil hibernating insects or eggs therefore were exposed to a greater degree of cold than —4.0°C., which previous studies have shown to be far above the lethal cold temperature for most of the economic species of insects.

It is of interest to note just what effect the snow covering had on subsurface temperatures for certain days. Four representative days are shown. On January 15, 1932, with an air temperature of —16.6°C. and seven inches of snow, the temperatures recorded are as follows:

Air temp	—16.6°C.	Soil surface	—1.1°C.
7 inches—snow level	—15.8	1 inch	—0.8
6 inches	—14.9	2 inches	0.5
5 inches	—13.9	3 inches	—0.3
4 inches	—11.3	4 inches	—0.1
3 inches	— 7.6	5 inches	0
2 inches	— 4.3	6 inches	+0.1
1 inch	— 1.4	6 feet	+6.7

[1]Contribution from Montana State College, Agricultural Experiment Station. Paper No. 20, Journal Series.

FEBRUARY 1932 MARCH

DATE	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
+ OR −	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+	+	+	−	+	+	−	+	+	−	+	+	+	−	+
AIR TEMP	13.3	12.2	13.3	8.9	5.3	0	2.5	3.3	2.5	3.1	4.4	8.1	11.1	8.1	4.4	1.1	1.7	11.1	11.4	5.0	19.3	16.7	23.3	25.0	24.7	20.6	14.4	7.8	1.9	2.8	1.4	1.9	4.4	5.9	0.6	2.2	0.6	0.8	2.5	1.4	0	3.5	6.1	0.6	0.6	8.9
10 INCHES			14 0																																											
9 "		7.4	12.8	7.3	5.9																																									
8 "	12.5	7.3	11.0	7.5	5.9	1.1																																							
7 "	13.1	7.1	9.5	7.2	6.7	2.6	0.8															16.3																								
6 "	13.2	6.4	8.0	6.4	6.7	2.8	1.0	2.4	2.8	1.8												15.7	26.8	26.5						0.9		4.2													
5 "	13.3	5.7	6.4	5.6	5.9	2.8	1.1	2.3	2.0	0	5.5											14.6	25.8	26.0	23.8	19.4				0.7		4.0													
4 "	12.3	4.8	5.0	4.7	4.9	2.4	1.1	2.2	1.2	1.2	4.5										12.3	10.1	21.8	23.5	22.8	22.2	19.9	11.5	2.7	0.4		3.8	5.8			1.4							6.2	4.3	3.9	2.6	
3 "	9.6	3.7	3.8	3.8	3.9	2.2	1.0	2.0	0.2	1.3	2.8	6.3							2.5	11.0	6.3	11.7	15.0	16.1	16.5	16.3	11.3	3.3	0.1			3.6	6.0			1.3	0.8					4.9	4.2	3.5	1.4	9.3
2 "	5.1	2.9	2.8	2.8	2.8	1.8	0.9	1.1	0.1	0.5	1.1	6.3	5.8	5.1	8.8	2.7		13.2	12.8	1.8	5.3	3.5	5.8	8.1	9.8	8.8	10.1	8.6	1.7	0	3.7	3.2	4.6		3.4	0.6	0.7				0.4	4.8	4.0	4.5	0.3	9.2
1 "	4.2	2.4	2.2	2.3	2.3	1.7	0.8	0.8	0	0.4	0	1.0	5.2	3.6	3.0	1.1	1.5	4.2	5.5	1.0	2.6	1.7	2.3	3.5	4.4	6.1	4.8	4.5	1.2	0.1	0.7	0.5	2.0	2.0	2.8	0	0	0	2.0	1.7	0.3	2.8	2.8	0.7	0.2	7.9
Soil Surface	3.8	2.3	2.1	2.2	2.2	1.7	0.8	0.7	0.3	0.4	0.2	0.4	0.8	1.8	0.7	0.3	1.0	2.5	3.9	0.9	1.9	1.4	1.8	2.8	3.4	4.0	4.0	3.7	1.1	0.1	0.2	0.1	0.2	0.6	0.8	0.7	0.7	0	0	0	0.2	0	1.4	0.4	0.2	4.6
1 INCH	3.6	2.2	2.0	2.1	2.1	1.6	0.8	0.6	0.3	0.4	0.3	0.4	0	0.6	0	0.2	0.5	1.3	2.4	0.7	1.0	1.1	1.3	2.1	2.7	3.3	3.3	3.0	1.1	0.2	0.1	0.1	0.7	0.2	0.5	0.7	0.7	0	0	0	0	0	0.8	0.5	0.2	2.7
2 INCHES	3.3	2.1	1.9	2.1	2.0	1.5	0.8	0.5	0.3	0.4	0.3	0.5	0	0.2	0	0.1	0.2	0.4	1.5	0.5	0.8	0.9	1.1	1.8	2.2	2.7	2.7	2.5	1.0	0.2	0.1	0.1	0	0	0.2	0.2	0.7	0	0	0	0	0	0.6	0.5	0.3	2.2
3 "	2.8	2.0	1.8	2.0	1.9	1.4	0.8	0.6	0.3	0.4	0.3	0.5	0.1	0	0	0.1	0.2	0	0.4	0.3	0.7	0.7	0.7	1.3	1.7	2.1	2.3	2.1	0.9	0.3	0.2	0.1	0	0	0	0.1	0.2	0.1	0	0	0	0	0.3	0.5	0.3	1.7
4 "	2.6	1.9	1.7	1.9	1.7	1.3	0.8	0.6	0.3	0.8	0.3	0.5	0.2	0.1	0.1	0.1	0.2	0	0.2	0.2	0.6	0.6	0.5	1.1	1.4	1.8	1.9	1.8	0.8	0.3	0.2	0.2	0	0	0	0	0.1	0.2	0.1	0	0	0	0.2	0.4	0.3	1.4
5 "	2.2	1.8	1.5	1.8	1.5	1.2	0.8	0.5	0.3	0.5	0.3	0.5	0.2	0.2	0.1	0.1	0.2	0	0.1	0.2	0.5	0.4	0.3	0.6	1.0	1.3	1.5	1.4	0.7	0.3	0.2	0.2	0	0	0	0	0.2	0.1	0	0	0	0	0.2	0.4	0.4	1.3
6 "	1.9	1.5	1.2	1.6	1.4	1.1	0.8	0.6	0.3	0.5	0.3	0.4	0.2	0.3	0.1	0.1	0.2	0	0.1	0.2	0.4	0.2	0.2	0.3	0.6	0.8	1.0	1.1	0.6	0.3	0.2	0.2	0	0	0	0.1	0	0	0	0	0	0	0.2	0.3	0.4	1.2
8 "	1.4	1.2	0.9	1.2	1.2	1.0	0.7	0.5	0.3	0.5	0.3	0.4	0.2	0.3	0.2	0.1	0.2	0	0.1	0.2	0.3	0.2	0.1	0.1	0.3	0.4	0.6	0.8	0.4	0.3	0.2	0.2	0	0	0.1	0	0	0.1	0.1	0	0	0	0.2	0.6	0.6	1.2
10 "	0.9	0.9	0.6	0.8	0.9	0.8	0.6	0.4	0.3	0.5	0.3	0.4	0.2	0.3	0.2	0.1	0.2	0	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0	0.1	0	0	0	0.1	0.1	0	0	0	0.2	0.1	0.2	0.3	0.8	1.2
12 "	0.4	0.4	0.2	0.5	0.6	0.5	0.4	0.3	0.3	0.5	0.2	0.3	0.1	0.2	0.2	0.1	0.2	0	0.1	0.1	0.1	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0.2	0.1	0.1	0.2	0.3	0.2	0.1	0.3	0.3	0.3	0.5	0.9	0.9	1.2
14 "	0.2	0.1	0.1	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0	0.1	0.1	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.4	0.3	0.2	0.4	0.4	0.3	0.2	0.4	0.4	0.4	0.7	1.0	1.0	1.2
16 "	0	0	0	0	0	0	0	0	0	0.2	0	0.1	0	0	0	0	0.3	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0	0.3	0.3	0.3	0.4	0.5	0.4	0.3	0.6	0.5	0.5	0.4	0.7	0.5	0.5	0.8	1.1	1.1	1.2
18 "	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0	0	0	0	0.1	0.2	0.2	0.2	0.4	0.3	0.2	0.2	0.3	0.4	0.4	0.3	0.4	0.3	0.2	0.4	0.4	0.4	0.5	0.7	0.5	0.4	0.8	0.7	0.6	0.6	0.8	0.6	0.6	0.9	1.1	1.2	1.3
20 "	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.2	0	0.2	0.1	0.2	0.2	0.3	0.4	0.4	0.6	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.6	0.6	0.7	0.6	0.8	0.6	0.7	0.9	0.8	0.7	0.7	0.9	0.8	0.8	1.0	1.2	1.3	1.4
22 "	0.4	0.6	0.7	0.6	0.5	0.6	0.5	0.5	0.4	0.4	0.5	0.2	0.5	0.3	0.4	0.6	0.5	0.8	0.6	0.6	0.6	0.7	0.7	0.8	0.7	0.7	0.6	0.6	0.7	0.7	0.9	0.7	1.0	0.9	0.8	1.0	1.0	0.8	0.8	1.0	0.9	0.9	1.1	1.3	1.4	1.5
24 "	0.6	0.8	0.9	0.7	0.7	0.8	0.7	0.7	0.6	0.7	0.6	0.4	0.5	0.6	0.6	0.8	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.9	0.9	1.0	0.9	1.2	1.1	1.0	1.2	1.2	1.2	1.0	1.2	1.0	1.1	1.2	1.4	1.4	1.6
3 FEET	1.9	2.1	2.0	1.8	2.0	2.0	2.0	1.9	1.8	1.8	1.7	1.7	1.7	1.6	1.7	1.8	1.7	1.8	1.8	1.7	1.7	1.7	1.9	1.8	1.7	1.7	1.7	1.6	1.8	1.8	1.8	1.8	2.0	1.9	1.7	2.0	2.0	2.2	1.8	2.0	1.8	1.9	2.0	2.0	2.0	2.1
4 "	3.1	3.1	3.1	3.0	3.0	3.1	3.0	3.0	2.9	2.8	2.4	2.6	2.8	2.7	2.6	2.9	2.7	2.9	2.6	2.6	2.6	2.6	2.6	2.7	2.6	2.7	2.5	2.4	2.6	2.6	2.7	2.7	2.7	2.5	2.4	2.7	2.8	2.8	2.5	2.7	2.6	2.7	2.7	2.7	2.6	2.7
5 "	4.4	4.3	4.3	4.1	4.1	4.2	4.2	4.1	4.0	4.1	4.1	3.8	3.8	3.8	3.8	3.9	3.7	3.9	3.7	3.7	3.7	3.6	3.7	3.6	3.6	3.5	3.6	3.5	3.6	3.6	3.7	3.6	3.6	3.4	3.3	3.7	3.7	3.5	3.4	3.6	3.4	3.5	3.6	3.5	3.4	3.5
6 "	5.4	5.3	5.3	5.0	5.0	5.1	5.1	5.0	4.9	4.9	5.0	4.8	4.8	4.7	4.7	4.8	4.6	4.8	4.6	4.6	4.6	4.5	4.5	4.5	4.4	4.4	4.4	4.3	4.4	4.4	4.4	4.4	4.4	4.3	4.2	4.3	4.4	4.3	4.2	4.3	4.3	4.3	4.3	4.2	4.2
SNOW COVER IN INCHES	8	9	10	9	9	8	7	6	6	5	3	0				2	1	2	2	3	4	7	6	6	5	5	4	4	4	2	1	0	0	0.5	2	4	3	1	0	0	2	0	0	3	1	0

Fig. 69.—Soil Temperature Record for February 15 to March 31 at Bozeman, Montana. All temperatures expressed in degrees Centigrade. Average daily air temperatures with + or — sign above. All temperatures between the heavy irregular lines are MINUS except where indicated by an asterisk. All other temperatures PLUS.

On January 25th we have the following data:

Air temp	—12.0°C.	1 inch	—1.4°C.
6 inches—snow level	—11.4	2 inches	—1.2
5 inches	—10.5	3 inches	—1.0
4 inches	— 9.0	4 inches	—0.8
3 inches	— 6.4	5 inches	—0.5
2 inches	— 3.7	6 inches	—0.3
1 inch	— 1.9	8 inches	0
Soil surface	— 1.7	6 feet	+6.2

During the month of Janauary, 1932, there was an extended cold spell from the 15th to the 31st, there being only one day when the average daily air temperature was above freezing. Yet during this extended cold spell the frost line penetrated only to ten inches. The snow during this period was from 6 to 11 inches deep. During the month of February the cold snap continued until the 20th, there being two days when the average daily air temperature barely rose above freezing. The frost line continued to be pushed down, apparently reaching to its greatest depth at 16 inches, remaining stationary at this depth for over a week. A typical record during this period is shown for February 17th:

Air temp	—15.0°C.	1 inch	—2.0°C.
10 inches—snow level	—14.0	2 inches	—1.9
9 inches	—12.8	3 inches	—1.8
8 inches	—11.0	4 inches	—1.7
7 inches	— 9.5	5 inches	—1.5
6 inches	— 8.0	6 inches	—1.2
5 inches	— 6.4	8 inches	—0.9
4 inches	— 5.0	10 inches	—0.6
3 inches	— 3.8	12 inches	—0.2
2 inches	— 2.8	14 inches	—0.1
1 inch	— 2.2	16 inches	0
0 Soil surface	— 2.1	6 feet	+5.3

From February 21st to 29th a warm spell occurred, the maximum daily average reaching 11.1°C. The snow melted rapidly and by the 26th had disappeared entirely. For those nine days the daily average air temperature was never below +2.5°C. No great effect of this thaw was observed in the soil temperatures but on the 24th, two days after the beginning of the thaw, the frost line dropped for one day from 16 to 20 inches, the next day rising to 18 inches. Whether this was due to the ground above the twenty-inch level warming up, withdrawing some heat from below and so extending the frost line four inches, it is hard to say. But 20 inches remains the maximum depth to which the ground was frozen. On this day the soil surface temperature was —0.4°C., and there was a temperature gradient through the top 20 inches of soil of only 0.5°C. During the month of March more snow fell and on March 9th there occurred the coldest day of the winter with an average air

temperature for that day of —25°C. The snow covering was only 6 inches and the temperature record for that day is shown hereunder:

March 9th:

Air temp	—26.5°C.	3 inches	—1.3°C.
6 inches—snow level	—26.5	4 inches	—1.1
5 inches	—26.0	5 inches	—0.6
4 inches	—23.5	6 inches	—0.3
3 inches	—15.0	8 inches	—0.1
2 inches	— 8.1	10 inches	—0.1
1 inch	— 3.5	12 inches	0
0 Soil Surface	— 2.8	14 inches	0
1 inch	— 2.1	6 feet	+4.5
2 inches	— 1.8		

It will be seen from this record that there was a rise in temperature of 23.2°C. in the five inches of snow above the soil surface. One of the most significant features brought out by this study is the fact that there is no correlation between the winter air temperatures and soil surface temperatures. During the six weeks represented by the chart shown (Fig. 69) the air temperatures at the time records were made, show a spread of 36.1°C., i.e., from a minimum temperature on March 8th of —26.8°C. to a maximum on March 31st of 9.3°C. During this same period the spread in soil surface temperatures was only 8.5°C., the minimum temperature being recorded on March 4th of —3.9°C. and the maximum soil surface temperature being recorded on March 31st with 4.6°C. If the sub-zero temperatures alone be considered, the discrepancy between the air and soil surface temperatures is even more marked, the spread in air temperatures being 26.8 degrees and that of the soil surface temperature being 3.9 degrees.

Four days after the coldest day recorded, i.e., March 9th, the frost line dropped from 14 to 16 inches but the next day rose again to 12 inches, and during the following two weeks of mild weather, the frost continued to come out of the ground, which was entirely thawed out by March 28th.

At a depth of six feet the daily fluctuations in temperature were small and from January to April the spread at that depth was only 3.2°C. from +7.2°C. to +4.0°C., which was the coldest temperature recorded at this depth for the winter.

It is of interest to note that after the snow had entirely gone, the air temperatures at inch levels above the soil surface also showed slight but decided differences, although not of great significance in ecological studies of insects at this time of the year. However, such temperature gradients during the season of maximum insect activity, especially during

the blistering heat of July days, will be large, and should have a decided influence on insect movements and behavior.

From the above discussion it will be readily seen that insofar as the ability of economic insects to survive the winter in the soil is concerned, this past season has been most favorable.

MORTALITY OF *RHAGOLETIS COMPLETA* CRESS. (DIPTERA: TRYPETIDAE) THROUGH INGESTION OF CERTAIN SOLID MATERIALS

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ABSTRACT

Ingestion studies in which lead arsenate, barium fluosilicate, cryolite, copper carbonate, hydrated lime, talc, diatomaceous earth, bentonite, sulfur, and ground tobacco leaves were employed, demonstrated that adult flies (*Rhagoletis completa* Cress.) actually take undissolved particles into the stomach. Results of toxicity studies in which the above materials were employed are graphically presented.

Laboratory and field studies on the toxicity of various materials to adults of the walnut husk fly, *Rhagoletis completa* Cress., have yielded interesting and curious information. These studies were begun in 1928, and conducted each season thereafter until and including 1931. A report covering the 1929 and 1930 studies, including details of technique and treatment of data, was published in the Monthly Bulletin of the California Department of Agriculture.[1]

Only a portion of the 1931 data are herewith presented. The procedure in the 1931 studies was identical to that of previous years except that 20 per cent sucrose, instead of 10 per cent was included for food in all tests.

Acid lead arsenate has been used since 1912 in controlling the apple maggot (*Rhagoletis pomonella* Walsh), and the cherry fruit flies (*R. fausta* O. S., and *R. cingulata* Loew). It was also used against the Mediterranean fruit fly (*Ceratitis capitata* Wied.) in the eradication campaign in Florida. The nature of the lethal action has not been definitely understood. In dealing with *R. pomonella*, certain workers have opined that lead arsenate is not ingested by the flies, since the particles are "strained out" of imbibed liquid by the relatively small

[1]Boyce, A. M. Effectiveness of certain materials in producing mortality of the walnut husk fly, *Rhagoletis completa* Cress. California Department of Agriculture Mo. Bul. Vol. 20, pp. 682–690, 1931.

openings of the pseudotrachea, of the suctorial disc, or labella. Thus, in order for the material to cause death, it would be necessary for the flies to ingest appreciable quantities of arsenic in solution. Considering the water-solubility of commercial acid lead arsenate, it seems improbable that lethal amounts could be obtained in this manner. However, quantities of the material may be readily dissolved in the saliva which the flies emit in normal feeding and which are subsequently imbibed.

In feeding studies on non-biting flies, Graham-Smith[2] found that the blow fly (*Calliphora erythrocephala* Mg.) readily ingests all particles measuring up to .006 mm in diameter, and that particles measuring up to .02 mm in diameter are drawn into the pseudo-trachea when two opposite interbifid grooves are made to communicate with each other. Furthermore, relatively large objects apparently pass directly into the month when the prestomal cavity is open during prolonged sucking efforts made by the flies. Thus these studies show that the structure of this type of mouth part permits ingestion of solid matter. The mouth parts of the blow fly are somewhat similar in structure and size to those of the walnut husk fly.

When *Rhagoletis completa* was first discovered infesting Persian walnuts in California, in 1928, basic lead arsenate was employed in field control experiments. Walnut foliage is particularly susceptible to injury from acid lead arsenate, which fact excludes this material from use. During the 1928 season, it was repeatedly demonstrated that, under laboratory conditions, the mortality rate of flies confined on walnuts treated with basic lead arsenate was discouragingly slow. For enlightenment on this matter, an effort was made to determine whether or not flies actually ingested the solid particles of lead arsenate

Ingestion Studies. In preliminary tests lead arsenate was colored with aniline blue, methyl green, orange G, and säurefuchsin, all of which are water-soluble stains. Individual tests were conducted in which the dyed material was dusted onto walnuts and flies caged on them. After several days confinement under such conditions, dissection showed that the gut of most of the flies contained material similar in color to that with which the lead arsenate was originally stained. Furthermore, excrement of the respective color used was present on the sides of the battery jar cage. This indicated that the flies had ingested the stained particulate matter; however, definite evidence was lacking since only the water-soluble stain itself may have been taken in. Therefore, similar

[2]Graham-Smith, G. S. Flies and Disease, Chapter V, pp. 63–67, 1913.

tests were conducted in 1929 and 1930, in which non-water-soluble stains were used. Of the many tested, Sudan *III*, which is soluble in alcohol, served the purpose most satisfactorily. A saturated solution of the stain was made and thoroughly mixed with a small amount of the lead arsenate (approximately 20 grams) thus making a paste. This was allowed to dry at laboratory temperature. When completely dry, the material was pulverized and the procedure repeated. After three or four successive mixings with the dissolved stain, the lead arsenate was the color of the stain, i.e., scarlet-red.

Lead arsenate, barium fluosilicate, cryolite, copper carbonate, hydrated lime, talc, diatomaceous earth, bentonite, sulfur, and ground tobacco leaves were stained in the above described manner. Individual cage tests of each material applied on walnuts as spray and dust were conducted. In these tests the materials were used undiluted, except for the 20 per cent sucrose that was included for food. Controls were maintained in which the walnuts were treated with sucrose only. Fifty flies were used in each test. Approximately 48 hours after the flies were confined on the treated walnuts, lots consisting of 25 flies from each test were removed, stupefied with ether, and dissected. All dissection was performed with the aid of a binocular microscope at a magnification of $\times$ 50. In all tests, over 98 per cent of the flies dissected had large quantities of stained material present in various portions of the alimentary canal; however, it was most abundant in the hind intestine. Varying amounts were also present on the suctorial disc. In the controls, the alimentary canal of all flies dissected was creamy white, with the exception of certain instances when the rectum presented a slightly brownish coloration.

Just prior to stupefaction for dissection, when the vial containing the flies was held so as to permit light to pass through the abdomen, the intestine containing stained material was plainly visible in most instances. This was not observed in any of the flies from control cages. In all tests, except where stained bentonite was employed, characteristic reddish excrement was present on the sides of the battery jar cage. The recta of most of the flies consuming bentonite was greatly distended and upon incision proved to be quite effectively plugged with a somewhat gum-like material. Apparently this colloidal substance had adsorbed relatively large amounts of moisture, resulting in greatly increased volume.

In the diatomaceous earth tests, microscopic examination of stained contents from various portions of the alimentary canal revealed the

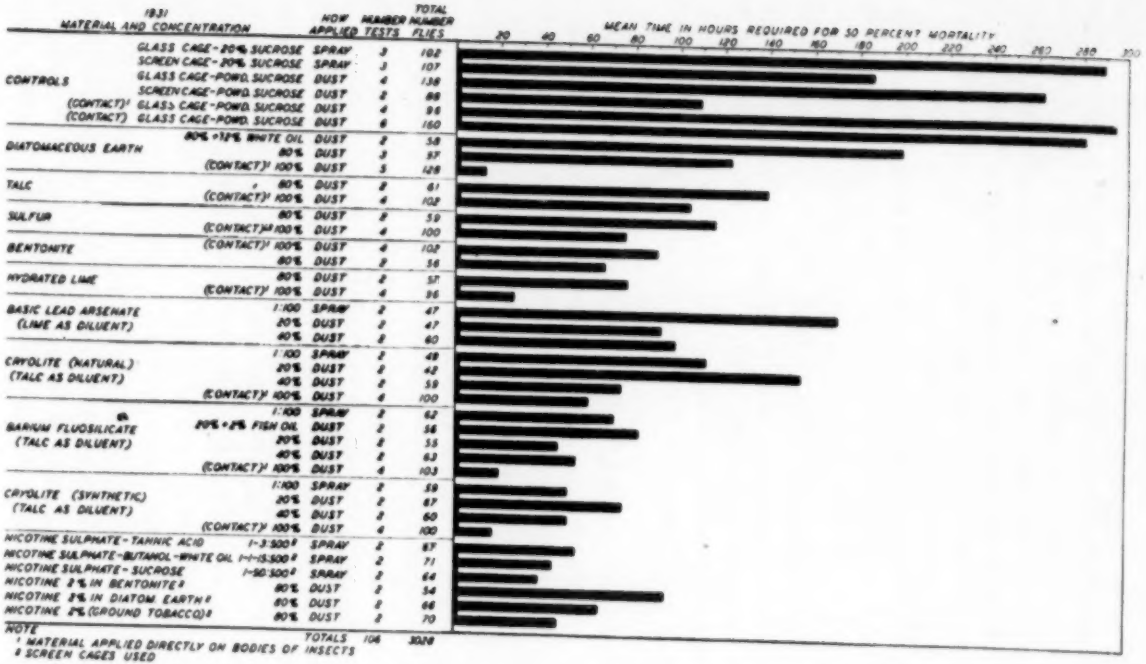
1931
MATERIAL AND CONCENTRATION
HOW APPLIED
NUMBER TESTS
TOTAL NUMBER FLIES
MEAN TIME IN HOURS REQUIRED FOR 50 PERCENT MORTALITY
20 40 60 80 100 120 140 160 180 200 220 240 260 300
CONTROLS
GLASS CAGE - 20% SUCROSE SPRAY 3 102
SCREEN CAGE - 20% SUCROSE SPRAY 3 107
GLASS CAGE - POWD. SUCROSE DUST 4 136
SCREEN CAGE - POWD. SUCROSE DUST 2 88
(CONTACT)[1] GLASS CAGE - POWD. SUCROSE DUST 4 98
(CONTACT)[1] GLASS CAGE - POWD. SUCROSE DUST 6 160
DIATOMACEOUS EARTH
80% + 1% WHITE OIL DUST 2 58
80% DUST 3 87
(CONTACT)[1] 100% DUST 5 126
TALC
80% DUST 2 61
(CONTACT)[1] 100% DUST 4 102
SULFUR
80% DUST 2 59
(CONTACT)[2] 100% DUST 4 100
BENTONITE
(CONTACT)[1] 100% DUST 4 102
80% DUST 2 56
HYDRATED LIME
80% DUST 2 57
(CONTACT)[1] 100% DUST 4 96
BASIC LEAD ARSENATE (LIME AS DILUENT)
1:100 SPRAY 2 47
20% DUST 2 47
40% DUST 2 60
CRYOLITE (NATURAL) (TALC AS DILUENT)
1:100 SPRAY 2 48
20% DUST 2 42
40% DUST 2 58
(CONTACT)[1] 100% DUST 4 100
BARIUM FLUOSILICATE (TALC AS DILUENT)
1:100 SPRAY 2 62
20% + 2% FISH OIL DUST 2 56
20% DUST 2 55
40% DUST 2 63
(CONTACT)[1] 100% DUST 4 103
CRYOLITE (SYNTHETIC) (TALC AS DILUENT)
1:100 SPRAY 2 59
20% DUST 2 67
40% DUST 2 60
(CONTACT)[1] 100% DUST 4 100
NICOTINE SULPHATE - TANNIC ACID 1-3,500[2] SPRAY 2 87
NICOTINE SULPHATE - BUTANOL - WHITE OIL 1-1-15,500[2] SPRAY 2 71
NICOTINE SULPHATE - SUCROSE 1-50,500[2] SPRAY 2 64
NICOTINE 2% IN BENTONITE[2] 80% DUST 2 54
NICOTINE 2% IN DIATOM. EARTH[2] 80% DUST 2 66
NICOTINE 2% (GROUND TOBACCO)[2] 80% DUST 2 70
NOTE
TOTALS 106 3029
[1] MATERIAL APPLIED DIRECTLY ON BODIES OF INSECTS
[2] SCREEN CAGES USED

Fig. 70.—Results of toxicity studies in 1931, showing mean time in hours required to bring about 50 per cent mortality of *Rhagoletis completa* Cress.

presence of diatome shells. Furthermore, these minute shells were found in the stained excrement taken from the battery jar cage of this particular test. These observations demonstrate conclusively that particulate matter is ingested by the flies while the evidence from the tests involving other materials is considered to be strongly indicative of this fact. Undoubtedly the flies imbibe these undissolvd particles in suspension in droplets of dew, or in their own saliva that is emitted in the process of feeding.

TOXICITY STUDIES. The 1931 toxicity studies consisted in determining the relative effectiveness of various materials in producing mortality of the flies The standard of comparison used in the meantime, in hours, required to produce 50 per cent mortality. A portion of the data obtained from these tests is summarized in Figure 70, which is self-explanatory. The material was applied onto the walnuts as spray or dust in all tests except those in which the contact effect of the material upon the body of the fly was tested. These tests are designated by the term "contact" in Figure 70. In these instances flies were placed in a glass container and subjected to a dense dust cloud of the particular material, and were then placed in the battery jar type cage regularly used, being confined on walnuts sprayed with stock sucrose solution. It is highly probable that the flies died as an indirect effect of the material having come in contact with their bodies, since they undoubtedly ingested relatively large amounts of the material as a result of their "cleaning up" habits. It was observed that for several hours after treatment they were constantly removing the dust from their bodies with their legs, the fore pair usually being cleaned with the mouth parts.

In those instances where volatile materials were employed, screen cages were used instead of glass, to obviate a fumigating effect. Controls were maintained for all test variations, i.e., glass cage, screen cage, sucrose applied as spray and dust, and dust as "contact" effect.

All diluent materials used (diatomaceous earth, talc, sulfur, bentonite, and hydrated lime) demonstrated lethal action upon the flies. The nature of this action is unknown; however, the following theories are suggested, realizing that they are highly problematical: Diatomaceous earth may seriously abrade the intima and epithelium, and possibly other tissues, of the alimentary canal. Talc may produce a diarrheal condition as a result of the cathartic action of magnesium, of which the content is relatively high. Sulfur may produce a highly acid condition in the digestive system, thereby causing deleterious metabolic disorders. Bentonite is colloidal in nature and apparently withdraws moisture from the

intestinal walls; however, without the usual flushing action but instead a clogging of the rectum as a result of increased volume due to water adsorption. Therefore, death may ensue from autointoxication as a result of failure to eliminate excrement. Hydrated lime may produce a somewhat hardened impervious layer on the inner lining of the alimentary canal, resulting in a failure to digest and assimilate food, thereby causing mortality through starvation. Likewise, starvation may be an important factor in mortality produced by diatomaceous earth, talc, and sulfur.

Of all materials used, diatomaceous earth was the most rapid in its lethal action when applied directly onto the bodies of the flies. It produced mortality much more slowly when flies fed upon it normally, and still more slowly when mineral oil was incorporated therein. Oil causes the earth particles to adhere more firmly to the surface of the nut, thereby apparently rendering it more difficult for the flies to "pick up" in feeding. Talc, sulfur, bentonite, and hydrated lime were also more rapid in their action when applied directly onto the bodies of the flies than when flies fed normally upon them. Apparently larger amounts of material are ingested during the removal of the material from their bodies than through normal feeding.

Basic lead arsenate exhibited relatively slow action and in spray tests was slower in producing mortality than in dust tests. Perhaps the dust particles are more readily ingested in quantities since the material does not adhere to foliage and nuts as firmly as when applied as spray. The performance of this material in 1931 was in accord with the 1929 and 1930 tests. The 40 per cent dust mixture was somewhat slower in action than the 20 per cent mixture. Considering the speed of action of hydrated lime, it is possible that the increased amount of this diluent material in the 20 per cent lead arsenate mixture was responsible for the observed difference in speed of action over the 40 per cent lead arsenate mixture.

Barium fluosilicate and synthetic cryolite (sodium fluoaluminate) on the whole exhibited similar speeds of toxic action. Fish oil incorporated in the barium fluosilicate mixture appreciably retarded its effect in producing mortality. The explanation of this fact is presumably that suggested previously for the diatomaceous earth and mineral oil mixture. Observation showed that the fish oil was not repellent to the flies. In the barium fluosilicate dust tests, the 40 per cent mixture was slower in its action than the 20 per cent mixture, which fact is not readily explained. In speed of action, natural cryolite was considerably inferior

to the synthetic material in these tests. Similar results were obtained by Hepburn in toxicity studies dealing with the Natal fruit fly, *Pterandrus rosa* (Ksh.).[2] The two materials are identical chemically, and that used in these tests was similar in physical properties. Possibly the synthetic material is more effective because the bond between the elements of the molecule is not as great as in the natural product, thereby liberating the fluorine more readily.

Considering the known toxicity of nicotine, the nicotine compounds and mixtures tested were relatively slow in their action as stomach poisons. The differences evidenced in speed of action of the various mixtures possibly indicates the degree to which the nicotine is bound within or by the respective compounds and mixtures.

The controls demonstrate that the inverted battery-jar cages afford more nearly optimum conditions for longevity than do screen cages. Furthermore, when food (sucrose) is supplied as spray the flies live longer in screen cages than when powdered sucrose is dusted onto the nuts. When powdered sucrose was applied directly to the bodies of the flies, it had no deleterious effect upon them.

NOTES ON PRODENIA PRAEFICA GROTE[1]

By R. A. BLANCHARD, *Associate Entomologist*, and C. B. CONGER, *Field Assistant*, *Division of Cereal and Forage Insects, Bureau of Entomology, U. S. Department of Agriculture*

ABSTRACT

Prodenia praefica Grote has caused considerable damage periodically in California, Nevada, and Oregon. Alfalfa is the principal crop attacked, although severe damage has occurred to a large number of other field and truck crops. Biological studies conducted during 1930 and 1931 and observations on control during the widespread outbreak of 1930 are given.

Outbreaks of *Prodenia praefica* Grote[3] occur at intervals throughout central and northern California, western Nevada, and southern Oregon,

[2]Ripley, L. B., and Hepburn, G. H. Non-arsenical fruit fly poisons. So. African Dept. Agr. Ent. Memoir No. 7, pp. 17–23, 1931.

[1]W. B. Cartwright made suggestions in the arrangement of this manuscript. Joe S. Wade supplied the bibliography of literature cited. Notes by B. G. Thompson in the files at Sacramento, Calif., were of assistance in preparing the manuscript. C. C. Wilson, of the Sacramento laboratory, and L. P. Rockwood, of the Forest Grove, Oreg., laboratory, supplied some data on distribution and parasites. All but the more common host plants were determined by S. F. Blake, of the U. S. Bureau of Plant Industry.

[3]Family Noctuidae.

with the latest general outbreak in 1930. This insect has been observed, or reported, throughout the area from Antelope Valley in Los Angeles County, Calif., north to Crook County, Oreg.,[3] and from the Pacific Coast east to Churchill County, Nev. It has occurred in destructive numbers at elevations ranging from 50 feet to approximately 5,000 feet above sea level.

Alfalfa is damaged most seriously; but beans, tomatoes, corn, cotton, sorghum, grapes, and, to some extent, fruit trees are attacked. Large losses of alfalfa seed were reported in Surprise Valley, Modoc County, Calif., where one rancher alone estimated his loss to be in excess of $10,000. Records given in this paper represent data obtained by the writers in the Sacramento Valley near the city of Sacramento during the seasons of 1930 and 1931, except as acknowledged.

TYPES OF DAMAGE. Several types of damage have been observed. Alfalfa is usually injured by larvae feeding upon the foliage, although seed alfalfa is most seriously damaged through destruction of the flowering parts. The terminal buds are also cut, so that they fall over and wilt. In some heavily infested fields the larvae gnaw the outer tissues of the stubble after the hay is cut, and this checks new growth, to a degree depending on the number of larvae present and the size of the areas affected. The stems of young beans are cut part way through, in true cutworm style, causing the plants to fall over and die. The stems of tomato plants are attacked in a similar fashion, but are less seriously injured because of their larger size. The tender inside leaves of sorghums are eaten, often until little more than the midribs are left. The tender portions of potatoes, beets, onions, carrots, grapes, raspberries, in fact, of almost every variety of plant, are likewise destroyed.

HOST PLANTS. The following is a list of the plants upon which larvae of this species have been observed to feed:

Alfalfa (*Medicago sativa* L.)
Bean (*Phaseolus* sp.)
Cotton (*Gossypium* sp.)
Tomato (*Lycopersicon esculentum* Mill.)
Sorghum (*Holcus sorghum* L.)
Onion (*Allium cepa* L.)
Sugar beet (*Beta vulgaris* var.)
Garden beet (*Beta vulgaris* var.)
Potato (*Solanum tuberosum* L.)
Sweetclover (*Melilotus* sp.)
Carrot (*Daucus carota* L.)
Sunflower (*Helianthus* sp.)
Grape (*Vitis* sp.)
Yellow star-thistle (*Centaurea solstitialis* L.)
Sowthistle (*Sonchus oleraceus* L.)
Russian-thistle (*Salsola pestifer* A. Nels.)
Foxtail (*Chaetochloa* sp.)
Cup Clover (*Trifolium cyathiferum* Lindl.)
Filaree (*Erodium* sp.)
Gumplant (*Grindelia* sp.)
Greenbriar (*Smilax californica* A. Gray)
Polygonum sp.
Lambsquarters (*Chenopodium album* L.)

[3]Notes by L. P. Rockwood.

Garden pea (*Pisum sativum* L.)
Pear (*Pyrus communis* L.)
Peach (*Amygdalus persica* L.)
Blackberry (*Rubus* sp.)
Morning-glory (*Ipomoea* sp.)
Prickly lettuce (*Lactuca scariola* L.)
Whiteflowering raspberry (*Rubus parviflorus* Nutt.)
California dewberry (*Rubus vitifolius* C. & S.)
Raspberry (*Rubus* sp.)
Charlock (*Brassica arvensis* (L.) Kuntze)

Alfalfa and morning-glory appear to be preferred hosts during the summer, with foxtail, filaree, gumplant, and range grasses preferred in early spring. It appears that this insect prefers wild hosts found in grazing areas and that it is forced to alfalfa by the drying up of the natural growth Migrating larvae have been observed to enter a pine woods and feed upon almost every available vine and shrub, and have been reported feeding upon mountain shrubs in large numbers at times when only a few larvae were present in cultivated fields.

SEASONAL HISTORY. Field observations supplemented by laboratory cages and "hootch" trap records indicate that in the vicinity of Sacramento there are three generations and a partial fourth in a year. Adults from pupae overwintering in alfalfa fields and border lands, as well as larvae from eggs laid by these moths, were taken in grassland areas. In 1931 the first moths were observed in the field on April 15. First-generation larvae were taken in pasture land May 9, 1931. These larvae were full grown at that time and were observed feeding on gumplant and filaree. No larvae of the first generation were taken from alfalfa, although regular sweepings were made.

There is considerable overlapping of the two later generations. In 1931 second-generation larvae were present in the field from early June until late July; third-generation larvae were present from mid-July until early September. Three moths taken in traps on September 3 were thought to represent a partial fourth generation. Rearing cages of larvae collected in the field late in the season also produced 2 adults out of a total of 30 living pupae.

DESCRIPTION AND HABITS OF THE INSECT. The ADULT varies in general color from gray to grayish purple, with a light gray or buff area extending in from the costal margin and posteriorly a little more than one-third the distance toward the anal angle of the front wing. A wide gray or purplish band bounded by light wavy lines extends near and roughly follows the outer margin of the upper wing. Eight fine, more or less distinct white lines run parallel along the veins from the outer margin of the band to that of the upper wing. Two light-colored lines follow the veins, converging at the humeral angle, cross the light area,

and meet the line forming the anterior margin of the dark band. The innermost of these lines branches with the veins posteriorly.

The following description by Grote[1] serves to distinguish this species from *P. ornithogalli* Guen.

> "Allied to the eastern *lineatella* (*ornithogalli*); a little larger, with broader wings. The hind wings are more obscure, in the female subfuscous. The markings are so nearly alike in the two that I do not find good differences. Nevertheless, the tone of the three Californian specimens is less bright, the whitish apical shade is less defined, and the discal point beneath on the secondaries is evident and distinct, whereas it is wanting in *lineatella*. The extra basal and subterminal fields show a purply shading in *praefica*. Expanse 36 mm."

When disturbed, the adults fly rapidly in a zigzag manner, sometimes considerable distances, before alighting and secreting themselves among the plant growth or trash on the ground.

The EGG is light gray, rounded, flattened at the base, with ribs converging at the top to form a small, nipplelike protuberance. The eggs are laid in masses which are covered with a layer of tiny dark gray scales from the ovipositor of the female. Oviposition takes place at night, usually on the upper surfaces of the leaves, although the eggs are occasionally found on the under surfaces. Counts of 14 egg masses taken in the field showed the number of eggs in a mass to range from 122 to 1,097, with an average of 500.

Difficulty was experienced in getting the females to oviposit in cages. One female deposited three masses on three consecutive evenings between 8:30 and 9:30, making a total of 701 eggs. She was observed ovipositing one mass on a glass vial, the process being as follows: The abdomen was held close to the glass and the ovipositor vibrated up and down on the spot selected for the egg. Each egg came down the tube with considerable force and was held in place by a sticky substance on the egg. The ovipositor was used as a feeler to locate a vacant place in the row of eggs already laid—an egg being placed alternately on the basal row and on the row above. The hairy covering on the tip of the abdomen was gradually removed in the process of egg laying. The abdomen was forced against the glass and the completed portion of the egg mass in such a manner as to pull the hairs loose and allow them to adhere to the

[1]Grote, A. R. Preliminary List of the Noctuidae of California. Part IV. Canad. Ent. 7: 44–49. 1875.

sticky surfaces of the freshly laid eggs. The ovipositor was used at times to aid in pulling the hairs loose. The act of ovipositing and of covering the egg was accomplished by one smooth, continuous motion. The abdomen was sometimes bent and twisted as the work proceeded. The female moved forward almost imperceptibly as she laid the eggs, but otherwise her legs were at rest at all times. Counts showed that an egg was laid every 7½ to 11 seconds. Approximately one hour was required for oviposition of the mass.

The average length of the egg stage for seven masses was 4.5 days, with five masses requiring 5 days and two masses requiring 3 days to hatch.

The newly-hatched LARVA is light in color with a black head. Full-grown larvae vary considerably. Black with distinct dorso-lateral yellow or white stripes and a faint mid-dorsal stripe is the most prevalent type. This type has a mid-lateral black band bounded on both sides by gray bands. Several variations of gray larvae with white stripes above and dark and light gray bands on the sides also occur. Regarding the larva of this insect Crumb[5] says: "This species closely resembles *Prodenia ornithogalli* in coloration but may be readily distinguished by the distinct fuscous reticulation on the fore part of the head * * * *."

The average length of the larval stage as observed by the writers in 1931 was 26.8 days for the second generation and 21.3 days for the third generation. The records of 48 larvae were obtained. Six and seven instars occurred in about equal number in captivity. The seventh instar may have been due to the artificial condition under which the larvae were reared.

Alfalfa was used as food for some of the larvae, whereas others were supplied with alfalfa and prickly lettuce. It was observed that the larger larvae preferred prickly lettuce and grew more rapidly than larvae supplied with alfalfa only. Larvae feeding on prickly lettuce and alfalfa combined were more easily able, when molting, to cast off the head mask than were those larvae feeding only on alfalfa.

Upon hatching, the larvae burrow through the covering of the egg mass, leaving the whitish perforated material upon the leaf. Here they feed a short while and then begin to disperse from the original leaf by spinning tiny silken filaments which allow them to be blown about by the breeze until they come into contact with other leaves. Here they feed

[5]Crumb, S. E. The Army Worms. Bul. Brooklyn Ent. Soc. (n. s.) 22: 41–55 1927.

on the upper surfaces of the leaves. In this manner larvae in the first and second instars often skeletonize the plant upon which eggs were laid. Frequently this dispersion by means of filaments is repeated several times, and this appears to be the chief means of dissemination up to the fourth instar, causing a rather intense distribution within an area of about 50 square feet around the locality where the eggs had been laid. Beyond the third instar the larvae disperse by their own locomotion.

Under normal conditions the larvae remain inactive during the night, resting at various heights on the plants. Activity begins about two hours after sunrise, when the larvae begin to feed. Only a few of the larger larvae feed at this time, but they move about on the ground, and by the middle of the morning they cease feeding entirely and confine their activity to the ground. First and second instar larvae do not migrate but continue to feed throughout the day in practically the same positions. By noon the migrating larvae seek plants and sticks in order to get off the warm soil, their movements being quick and apparently in no special direction. Those on the alfalfa feed rather intensively and descend to the ground only long enough to reach another plant. The larvae remain upon the plants and continue to feed until late afternoon, when, as the ground becomes cool, the activity there is resumed and the second migration of the day occurs. This migration is relatively short, and by late dusk the larvae become dormant again, some on the plants and the others on the ground.

THE PREPUPA AND PUPA. Upon reaching maturity the larva burrows into the ground to a depth of 1½ to 2 inches, lines the hole thus formed with a thin web, and covers the opening with a circular layer of moistened soil. The pupa is at first a light cream color but changes to mahogany red after a few hours. The average length of the prepupal period for 16 individuals of the first generation was 3.1 days, with a maximum of 5 days and a minimum of 1 day. The pupal stage of 9 individuals of the first generation required an average of 18 days for completion, with a maximum of 22 days and a minimum of 16 days. The length of the prepupal stage ranged from 1 to 4 days during the second generation, with an average of 2.6 days for 23 individuals. The length of the pupal stage for 13 individuals of this generation ranged from 14 to 25 days with an average of 15.3 days. The average prepupal period for 7 individuals of the third generation was 1.9 days, with a maximum period of 3 days and a minimum of 1 day. Two individuals of the third generation remained in the pupal stage 16 and 31 days, respectively. All other reared larvae or larvae of this generation collected in the field re-

mained in hibernation in the pupal stage. This species hibernated only in the pupal stage, according to records from the vicinity of Sacramento.

The lengths of the larval instars and pupal stages observed for second and third generation insects are shown in Table 1. For the second generation the average length of the larval stage of those larvae having seven instars was 28.4 days, whereas larvae having only six instars had an average larval period of 25.9 days. In the third generation, larvae passing through seven instars required 21.5 days to mature, as compared with 20.7 days for larvae having six instars.

NATURAL CONTROL. A POLYHEDRAL DISEASE was the most important factor in natural control observed by the writers. This disease affects larvae in the fourth to last instars, turning them reddish brown before death, after which the body cells distintegrate rapidly into a dark, watery mass which hangs limply on the leaves and stems.

A FUNGOUS DISEASE killed a small percentage of prepupae confined in cages. Larvae killed by this disease were also observed in small numbers in the field. Owing to the difficulty in finding prepupae in the soil, however, the disease may be more prevalent than was apparent.

INTERNAL PARASITES. *Chelonus texanus* Cress. was the most important hymenopterous parasite noted by the writers. This cosmopolitan species oviposits in the egg of its host. When in the fourth instar, the parasitized larva enters the soil and forms a small but normal cell. The parasite larva emerges in 16 to 20 days after oviposition and spins a small white cocoon in the soil. The adult issues from 8 to 12 days later. The records of 1931 show the hymenopterous larva *Hyposoter exiguae* Vier. emerging from fourth-instar larvae. The Hyposoter spins a small gray cocoon on the alfalfa leaf and remains in this stage 10 to 16 days, or 12 days as an average. Other hymenopterous parasites that have been reared from pupae of *P. praefica* are *Amblyteles difficilis* Cress., *Apanteles marginiventris* Cress., *Cryptus tejonensis* Cress., and *Meteorus vulgaris* Cress.

Archytas californiae Walk. (Tachinidae) was the most important dipterous parasite noted and perhaps the most important of all the species thus far observed. This large fly emerges from the pupa of its host. Pupae parasitized by it usually have swollen or otherwise deformed wing pads. About the time the puparium of the fly is formed, a fungous growth appears outside the host. This growth is apparently occasioned by exudations of body fluids from breaks in the skin of the parasitized pupa. Two other dipterous parasites have been reared. *Eucelatoria armigera* Coq. issued from the prepupa and formed its puparium in the

TABLE 1. LENGTH OF LARVAL INSTARS AND PUPAL STAGES OF *Prodenia praefica*

	Egg masses	Larval instars									
		I	II	III	IV	V	VI	VII	Larval	Pre-pupal	Pupal
	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days
Second generation											
Maximum	5	5	4	7	7	8	13	11	34	4	25
Minimum	3	2	1	2	2	2	2	5	23	1	14
Average	4.5	2.5	2.8	3	3.4	4.5	5.2	6.9	26.8	2.6	15.3
Number of individuals	7	35	35	35	35	35	35	13	35	23	13
Third generation											
Maximum	–	2	2	2	3	6	10	8	26	3	31
Minimum	–	2	1	2	2	3	3	5	20	1	16
Average	–	2	1.1	2	2.4	3.3	4.6	6.9	21.3	1.9	23.5
Number of individuals	–	13	13	13	13	13	13	9	13	7	2

soil. From one to seven puparia have been formed from a single host. *Phorocera claripennis* Macq. was also reared from this species, but the stage from which it emerged was not observed. The phorid fly, *Aphiochaeta* sp. was reared by B. G. Thompson from several lots of material collected near Plymouth, Calif. As many as 130 adults have issued from one larva.

PREDATORS. The redwinged blackbird and the bronzed grackle often destroy incipient infestations. Both species feed upon the larvae in large numbers when alfalfa is being cut and raked. A species of ant (undetermined) preys upon small larvae. The spined soldier bug (*Sinea diadema* Fab.) has occasionally been observed feeding upon the larvae and, as it is fairly numerous in alfalfa fields, it is probably a predator of some importance.

VITAL STATISTICS. In order to determine the relative importance of the parasites and other factors in the control of *P. praefica*, 1,059 larvae in the second last instars were collected in the field in the lower Sacramento Valley during 1931, and confined at the laboratory in individual 2-ounce tins This study covered the period July 15 to August 31. The results are shown in Table 2.

All the unknown species of parasites, which constituted 2.8 per cent of the total, died in the larval stage. Most of them appeared to be *Chelonus texanus*. It is considered that, with the exception of the second instar, a fairly representative number were obtained of each stage of *Prodenia praefica* present at the time of sampling. This instar is unimportant in any case, as no parasites have been observed to affect it.

The only break in sampling occurred between August 8 and 19. This period does not appear to affect the results, as most of the larvae were then in the fifth and sixth instars. The sample taken on August 8 would have included those parasites that affect larvae up to the fifth instar—namely, *Chelonus texanus* and *Hyposoter exiguae*. *Eucelatoria armigera* emerged from the prepupa and *Archytas californiae* from the pupa and would therefore be included in the sample taken on August 19.

CONTROL METHODS. The methods used in the control of this insect are those which are in more or less general use in army-worm control. Cutting of alfalfa just before the damage becomes serious gives good results. Such cutting causes the larvae to migrate. Birds and other predators often destroy a large percentage of the population of a field at that time. Larvae migrating from alfalfa into fields of beans, tomatoes, or other uninfested crops have been checked by plowing a furrow around the field to be protected. Where the soil is not too hard or dry this

TABLE 2. VITAL FACTORS IN REARING FIELD-COLLECTED LARVAE OF *Prodenia praefica*, JULY-AUGUST, 1931

Date collected	Dead				Number parasitized and percentage of parasitism										Surviving	
	Diseased		Unknown cause		*Chelonus texanus*		*Archytas californiae*		*Hyposoter exiguae*		*Eucelatoria armigera*		Unknown species		*P. praefica* forms	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
July																
15	38	71.7	3	5.7	0	0	0	0	0	0	0	0	2	3.7	10	18.9
18	74	81.3	7	7.7	0	0	5	5.5	0	0	0	0	0	0	5	5.5
21	41	83.7	3	6.1	0	0	4	8.2	0	0	0	0	0	0	1	2.0
22	28	75.7	1	2.7	2	5.4	0	0	0	0	0	0	6	16.2	0	0
23	35	87.5	5	12.5	0	0	0	0	0	0	0	0	0	0	0	0
27	20	83.3	3	12.5	0	0	0	0	0	0	0	0	1	4.2	0	0
28	33	49.2	18	26.9	11	16.4	0	0	0	0	0	0	2	3.0	3	4.5
31	74	77.9	14	14.7	4	4.2	0	0	0	0	0	0	2	2.1	1	1.1
August																
4	53	57.0	11	11.9	23	24.7	0	0	0	0	0	0	6	6.4	0	0
8	58	59.1	15	15.3	15	15.3	3	0	0	0	0	0	2	2	5	5.2
19	61	25.2	85	35.1	12	5	43	17.8	0	0	14	5.8	8	3.3	19	7.8
20	17	77.3	1	4.5	0	0	2	9.1	0	0	0	0	0	0	2	9.1
20	65	86.7	3	4.0	0	0	2	2.7	0	0	1	1.3	1	1.3	3	4.0
25	18	45.0	7	17.5	1	2.5	11	27.5	0	0	1	2.5	0	0	2	5.0
26	3	17.7	4	23.5	4	23.5	0	0	6	35.3	0	0	0	0	0	0
31	4	66.6	0	0	0	0	0	0	1	16.7	1	16.7	0	0	0	0
Totals and averages	622	59.3	180	17.2	72	6.9	70	6.7	7	0.7	17	1.6	30	2.8	51	4.8

method is very efficient, but in dry, hard soil it is only moderately successful. In the latter case a system of double furrows often completely protects the uninfested crops. Postholes at intervals in the furrows or poisoned-bran mash spread in the furrows should aid greatly in control. A log dragged up and down the furrows has been observed to be of value. Gear oil or other heavy oil lines act as barriers as long as they are not allowed to become covered with dust or dirt; such barriers have been used successfully across bridges and little-used roadways. Irrigation ditches filled with water have also been used. Still water is a better barrier than running water, as in the latter the worms have been observed swimming diagonally across stream in considerable numbers. Screen traps placed at intervals in swiftly moving water have been used with some success. The larvae must be removed from such traps at intervals, entailing considerable labor where the front to be protected is very long.

In fields of seed alfalfa, where cutting is out of the question, good results have been reported with the use of a spray composed of 4 pounds of lead arsenate to 100 gallons of water to which are added 3 quarts of blackstrap molasses. Such poisoning operations are best carried out while the larvae are still small, at which time they are generally concentrated in small areas over the field.

In the first experiments with poisoned-bran baits the precise directions for grasshopper control were followed, the mash being scattered broadcast over the infested area early in the morning. Careful observations revealed that most of the larvae did not stop to feed on the scattered particles and that the bran rapidly dried out to a point where none of the larvae would feed. In subsequent experiments the same bait was spread ahead of the advancing larvae in strips, each strip 3 or 4 inches wide and separated about 3 feet. The larvae were forced to cross over the bran and invariably fed on it. Also, the mash, being in a rather large mass, tended to retain its moisture and thus its effectiveness.

Four poisons were tested separately in bran mashes consisting of 25 pounds of wheat bran and 2 pounds of blackstrap molasses: Paris green 1 pound, sodium fluoride 1 pound, white arsenic 1 pound, and liquid sodium arsenite ½ pint. Red wheat bran was used in each case and as much water was added as the bran would absorb. Baits containing Paris green and sodium fluoride gave very good control in four experiments, whereas those with sodium arsenite and white arsenic gave poor results.

Several experiments in the use of calcium arsenate dust were made on beans and alfalfa. Field results were uncertain, although good control was obtained rather consistently by dusting larvae in cages with calcium

arsenate alone or mixed with equal parts of hydrated lime. Farmers throughout the Sacramento Valley were using straight calcium arsenate at the rate of 20 pounds per acre as a dust upon tomatoes and other truck crops, and were reported to have obtained good results.

SOME EFFECTS OF CERTAIN TOXIC GASES ON THE BLOOD OF THE COCKROACH, *PERIPLANETA ORIENTALIS* (LINN.)

By W. Earl Shull, Merrill K. Riley and Charles H. Richardson, *Department of Zoology and Entomology, Iowa State College, Ames, Iowa*[1]

Abstract

Only a few of the toxic gases used in this study produced a visible effect upon the process of blood coagulation, or upon the blood cells of *Periplaneta orientalis*, or brought about readily visible chemical changes in its blood. Roaches which were killed with carbon disulphide yielded a small quantity of blood poor in cells; those killed with pyridine also yielded little blood but the cell content was apparently normal. The blood of roaches, which were killed with acetic acid vapor, did not coagulate and the cells were fixed in an apparently normal condition. Crystals of magnesium ammonium phosphate appeared in the blood of the roaches which succumbed to ammonia gas. As these were the only effects observed in the blood of roaches treated with 34 inorganic and organic compounds of widely differing physical properties and chemical composition, it is probable that lethal concentrations of most gaseous compounds do not produce marked visible changes in the blood of this insect.

The visible effects of toxic chemical compounds on the blood of insects, especially on the processes of coagulation, on the morphological elements, and on the chemical constituents, have not been extensively treated in the literature. The investigation herein reported is a preliminary study of the effect of certain gases on the normal coagulation of the blood of the cockroach, *Periplaneta orientalis*. Other visible effects have also been noted.

The cockroaches which were subjected to the gases, were placed in small cages made of glass tubing, both ends of which were closed with cheese-cloth. The cages were then suspended over the compound to be tested in an ordinary gas bottle. The insects were allowed to remain in the bottle until dead, cessation of body movements being used as the criterion of death. All observations were made at room temperatures

[1]The writers wish to thank Dr. J. Franklin Yeager, Iowa State College, for the suggestions made during these studies.

which varied from 23 to 32 degrees Centigrade. The concentration of the gases approached saturation at these temperatures, but no effort was made to control the concentrations accurately.

The blood was obtained in the following manner: As soon as the roach was dead, an antenna was cut off, and by application of slight pressure to the body, the blood was forced in a drop from the severed end. It was collected in a drop of Nujol oil on a glass slide, and observed under the compound microscope. An examination was made of the blood of five cockroaches, (in most cases), which had been treated with each compound.

Yeager, Shull and Farrar (1932) have described the coagulation of the blood of the cockroach. As the cells flow from the cut end of the antenna, they are mostly spindle-shaped but they quickly become rounded and more refractive; they soon develop long and short pseudopods, and become "sticky." Coagulation occurs shortly, and after a time, the cells apparently disintegrate. Normal coagulation referred to in this paper corresponds with the picture just described.

The following thirty-four compounds were tested: Ammonia, hydrochloric acid, carbon disulphide, methyl alcohol, ethyl alcohol, carbon tetrachloride, chloroform, 1, 2-dichloroethane, trichloroethylene, tetrachlorethylene (CCl_2:CCl_2), pentachloroethane, diethyl ether, acetic acid, amyl acetate, hydrogen cyanide, benzene, nitrobenzene, chlorobenzene, paradichlorbenzene, cyclohexane, bromocyclohexane, methylcyclohexane, xylene (U. S. P.), cymene, toluidine, dimethylaniline, diethylaniline, methyl salicylate, pyridine, nicotine, naphthalene, tetrahydronaphthalene, limonene and d-camphor.

Cockroaches which were treated with carbon disulphide yielded very little blood, which contained few cells in proportion to the volume of blood. These cells were much more granular than those cells found in the untreated insects and in the insects which were treated with the other compounds. The scarcity of blood cells made it very difficult to study the process of coagulation but no morphological changes were noticed in the preparations.

Those insects which were treated with pyridine also yielded little blood but the cell content was apparently normal; otherwise the process of coagulation was normal and no other changes were observed.

Those animals which were treated with ammonia were killed in from three to five minutes, and the blood coagulated very rapidly. Crystals were observed in some of the preparations as soon as the blood was taken from the antenna, whereas, in others, the crystals did not appear until

after the blood had remained in the oil for some time. In all cases, the crystals finally became very numerous throughout the preparation, and corresponded in size, shape and color with the crystals of magnesium ammonium phosphate described and figured by Hawk and Bergeim (1931).

Acetic acid apparently fixed the cells so that they resembled those in uncoagulated blood. Even after a period of twelve hours, the cells retained their natural shapes, except that they became somewhat flattened after they had settled onto the slide. In a study of the blood coagulation in the cockroach (1932) it was observed that coagulation of the blood was prevented in roaches which had been heated for certain lengths of time and at certain temperatures, that the cells were randomly distributed in the preparation, and that they retained their natural shapes. Acetic acid apparently produces similar effects. Further study is being made of the effect of this compound on the blood.

All other compounds used in these studies produced no apparent effects on the coagulation of the blood or on the appearance of the cells.

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SOME RESULTS WITH PYRETHRUM IN THE CONTROL OF *MINEOLA SCITULELLA* HULST (LEPIDOPTERA, PYRALIDIDAE)

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ABSTRACT

Promising results were obtained with sprays containing Pyrethrum in experiments to control *Mineola scitulella* Hulst, a pest of the prune in southwestern Idaho, A summary of the life history of the insect is given. The materials tested were Pyrethrum extracts used in combination with kerosene emulsion, soap, and dormant type oil; a Pyrethrum-rotenone preparation; nicotine sulphate and nicotine preparations; lime-sulphur and lead arsenate. Best results were obtained with a kerosene solution of Pyrethrum in a kerosene-soap emulsion spray, which gave a kill of 93%. The larvae became greatly activated in the buds sprayed with this material, the activity ceasing in about two hours, after which time death occurred.

This insect is known as the destructive prune worm which during recent years has become important as a pest of the prune in southwestern Idaho. There are two generations and a partial third annually. The insect spends the winter as partly grown larvae in small wart-like hibernacula constructed in the crotches of buds and twigs, and in bark depressions. The hibernacula vary from one to three millimeters in diameter. The larval emergence starts in the early spring, usually from March 15 to 20, and is completed early in April. These overwintering larvae are from 1.5 to 6 millimeters in length, are light brown to a chocolate brown in color. As soon as the larvae emerge, they bore into the blossom buds and feed on the flower parts, consuming all but the bud scales. One larva may destroy several buds. The larvae become full grown in two to four weeks, and are then from 10 to 12 millimeters in length. They drop to the ground to pupate, and the moths start to emerge about May 15 and continue to emerge through June. The eggs are laid on the underside of the leaves, are a light reddish brown, slightly elongated, are about .4 millimeter in diameter, and hatch in seven to ten days. These first generation larvae enter the green prunes, feed on the interior and in about three weeks leave the fruit, drop to the ground and pupate. The second generation moths start to emerge in July, the eggs are laid as in the first generation, and as they hatch, the larvae enter the ripening fruit. Here they feed a short time then leave the fruit to spin the hibernacula in which they hibernate. A few of the second generation larvae remain in the fruit until full grown and produce a partial third generation.[1]

[1]From Life History of *Mineola scitulella* Hulst by Claude Wakeland, University of Idaho, (unpublished).

TABLE 1. SPRAY TESTS ON *Mineola scitulella* HULST

Plot No.	Spray materials	Spray date	Place	Total larvae	Live larvae	Dead larvae	% dead	Notes
5	Pyrocide No. 40, 1 part to 400; Kerosene 6% (emulsified); Soap (C.P.O. solid) 2.5 lbs. to 100 gal. spray	March 29	Parma	65	38	27	41.53	Dormant Spray; Spray pressure 350 lbs. Air temperature 52°F. Water Temp. 50°F.
6	Pyrocide No. 40, 1 to 400; Kerosene 6% (emulsified); Soap (C.P.O.) at 1 oz. dry weight per gallon spray	April 8	Emmett	275	19	256	93.09	Pressure, 350 lbs. Air, 50°F. Water, 44°F.
6A	Same as Plot No. 6	April 9	Parma	92	6	86	93.47	Pressure, 150 lbs. Air, 62°F. Water, 50°F.
7	Pyrocide No. 40, 1 to 400; Blood albumin, 2 oz. to 100 gal.; Dormant oil, 3% (tank mix)	April 8	Emmett	198	57	141	71.21	Pressure, 350 lbs. Air, 50°F. Water 44°F.
8	Pyrocide No. 20, 1 to 200; Ivory soap, 1 oz. to 1 gal. spray	April 8	Emmett	86	43	43	50.00	Pressure, 350 lbs. Air, 50°F. Water, 44°F.
8A	Pyrocide No. 20, 1 to 200; C.P.O. soap, 1 oz. (dry wt.) to 1 gal.	April 9	Parma	58	18	40	68.96	Pressure, 150 lbs. Air, 62°F. Water, 50°F.
9	Soluble Palustrex 'A' (containing 2.5% free nicotine), 2 to 100	April 8	Emmett	131	120	11	8.39	Pressure, 350 lbs. Air, 54°F. Water, 44°F.
10	Nicotine sulphate, 1 to 400; Dormant oil (emulsion), 3%	April 8	Emmett	265	230	35	13.20	Pressure, 350 lbs. Air, 56°F. Water, 44°F.
10A	Same as Plot No. 10	April 9	Parma	35	17	18	51.42	Pressure, 150 lbs. Air, 62°F. Water, 50°F.
11	Cubor (Pyrethrum and Rotenone), 1 to 200	April 8	Emmett	129	94	35	27.13	Pressure, 350 lbs. Air, 56°F. Water, 44°F. Pressure, 150 lbs.

11A	Same as Plot No. 11	April 9	Parma	51	36	15	29.41	Air, 62°F. Water, 50°F.
12	Lime Sulphur, 5° Baumé	April 12	Emmett	61	57	4	6.55	Pressure, 350 lbs. Air, 76°F.
13	Aphex Emulsion (dipyridyl oil, 25%), 1 to 40	April 13	Parma	39	18	21	53.84	Pressure, 150 lbs. Air. 78°F. Water, 50°F.
14	Soluble Palustrex 'A' (containing 2.5% free nicotine), 2 to 100	April 13	Parma	97	66	31	31.95	Same as Plot No. 13
15	Nicotine sulphate, 1 to 800; Dormant oil (emulsion), 3%	April 13	Parma	126	105	21	16.66	Pressure, 350 lbs. Air, 78°F. Water, 50°F.
16	Pyrocide No. 40, 1 to 800; Kerosene 3% (emulsified); C.P.O. soap, ½ oz. (dry wt.) to 1 gal. spray	April 13	Parma	236	36	200	84.74	Same as Plot No. 15
17	Lime sulphur, 4° Baumé; Lead arsenate, 2 lbs. to 100 gal.	April 11	Boise	19	18	1	5.26	
18	Check (no spray)	April 11	Emmett	152	152	0	00	

Pyrocide No. 40 is a kerosene solution of Pyrethrum containing 4.32 grams pyrethrins per 100 c.c.
Pyrocide No. 20 is an alcohol solution of Pyrethrum containing 2.15 grams pyrethrins per 100 c.c.
Dormant Oil: 65% unsulphonatable; 110 seconds viscosity @ 100° F., Saybolt Universal.
Soap: Ivory, neutral; C.P.O., trace of alkalinity.

The insect is a serious pest of the prune in the Boise and Payette Valleys of southwestern Idaho. As high as 50% of the crop has been lost in individual orchards because of the larval injury to the fruit. Some damage is done by the destruction of many blossom buds.

During the past three years many spray programs have been tried in an effort to control this pest. Nicotine sulphate at times gave some promise when applied early in the spring, but during the limited spray period, the air temperatures would vary from 50°F. to 75°F. Fair kills were sometimes obtained at temperatures above 70°F., but at the usual temperatures of around 60°F. the nicotine sulphate failed to give any appreciable kill. Other materials that have failed to give control were dormant oils, applied both during the dormant period and just after spring emergence of larvae, lime-sulphur with and without lead arsenate, pine oil, fluorine compounds, and certain commercial Pyrethrum sprays. The sprays were applied against the larvae within the hibernacula and also after the spring emergence when they were feeding within the buds The hibernacula proved to be practically impervious to most of the materials. The larvae in the buds proved to be nearly as well protected. Before boring into the bud, the larvae spin a dense web in the crotch of the bud and twig, then bore into the side of the bud near the base and cover the entrance hole with more webbing. As feeding progresses, frass is forced outside into the webbing and seems to offer increased protection against the spray materials. The difficulty encountered seemed to be the failure of the insecticides to reach the larvae. The nicotine sulphate seemed to penetrate the webbing and frass to some extent at higher temperatures, but was almost totally ineffective at 60° F. or lower.

The 1932 control experiments discussed in this paper included one dormant spray plot (No. 5), and 16 plots where the sprays were applied after emergence. Emergence counts of the overwintering larvae were made at intervals, and the sprays were applied from two to six days after 94% of the larvae had emerged. The sprays (excepting plot No. 5) were directed against the larvae as they were feeding within the buds and before any had dropped to the ground to pupate. The bud development at this time was that which is commonly called "delayed dormant," or when the buds are swollen and starting to show green at the tips. Three days after spraying, infested buds were gathered and the counts made. The results are given in Table 1.

The prune trees used were of medium size and required from five to six gallons spray to thoroughly wet the infested buds. No injury to the

buds from any of the materials was observed. The Aphex emulsion, Plot 13, caused some burning to the grass and alfalfa around the trees. A commercial power sprayer was used for most tests and a pressure of 350 pounds maintained. A few tests were repeated with a barrel sprayer at 150 pounds pressure, and there was no decrease in kill due to reduced pressure.

In the plots on which sprays containing Pyrethrum were used, the larvae showed considerable activity immediately after the trees were sprayed. The larvae attempted to leave the buds within which they were feeding. Most of this activity ceased in about two hours and death followed. Many of the larger larvae and some of the smaller ones succeeded in getting partly or entirely outside the bud before death, and a number were later found dead, swinging by a thread of silk an inch below the bud. Most of the dead larvae within the buds were found with their heads in the entrance hole, this position being just the reverse of that of the live larvae in unsprayed buds. The dead larvae of Plot No. 16 were in the positions as given in Table 2.

TABLE 2

Position of Larvae	No. dead larvae
Outside of bud and webbing	29
Within webbing	38
Partly outside bud	42
Within bud	91

There were 55 live larvae in the counts from plots No. 6 and No. 16 three days after spraying and of these 24 or 43% were inactive, apparently paralyzed, and partly discolored.

The air temperature was taken from a thermometer hanging in a tree near the plots. A comparison of temperatures for plots No. 6 and No. 6A shows a difference of 12°F. air temperature and 6°F. water temperature, but with no material difference in kill. The temperatures of April 8, were as low as may be expected during spraying at this time of year.

The materials used on plots No. 6 and No. 16 gave the most promising results, with 93.09% kill and 84.74% kill respectively. The materials in the spray used on plot No. 16 were reduced to one-half the amounts per 100 gallons of those used in the spray on plot No. 6.

THE EVALUATION OF STOMACH POISONS FOR GRASSHOPPER BAITS

By CHARLES H. RICHARDSON and LOUISE E. HAAS[1]

ABSTRACT

Adults of the red-legged grasshopper, *Melanoplus femur-rubrum* (Deg.) and the differential grasshopper, *M. differentialis* (Thomas) were fed determined quantities of bran, molasses and water bait which contained known concentrations of arsenious oxide, monosodium arsenite in solution, trisodium arsenite in solution, Paris green, acid lead arsenate, sodium fluosilicate or rotenone. The method is described. The estimated median lethal dose (M.L.D.) of arsenious oxide is 0.36 milligram per gram of body weight. For the sodium arsenites, Paris green and sodium fluosilicate, the M.L.Ds. are approximately equal and estimated to be about 0.16 mg./gram. The M.L.D. for acid lead arsenate is > 3.0 mg./gram and for rotenone probably > 2.0 mg./gram. For survival periods less than 96 hours, monosodium arsenate was more toxic than the other compounds. Under experimental conditions, the grasshoppers were not repelled by the odor or taste of the bait mixtures used, and ceased to feed only when they became satiated or were too sick to eat more. If undisturbed, they usually consumed a toxic dose of an active poison before leaving the bait.

Since the introduction of the poisoned bran bait for the control of grasshoppers in California in 1885, considerable research and extensive practical experience in many parts of the world have established the utility of baits for the suppression of these insects. Although numerous changes have been made in the kind and proportions of the poisons and other ingredients in attempts to improve this bait, it is still deficient in several particulars. It is slow in action; it is toxic to higher animals; it is often criticized as repellent, especially to young grasshoppers. Furthermore, conclusions in regard to the toxicity of the various poisonous ingredients have been based upon field or laboratory experiments which are now known to give at best only a partial or imperfect answer.

The grasshopper outbreak in Iowa during the summer of 1931 brought some of these questions to the fore, and the experiments described below were undertaken in an attempt to contribute something toward their solution. The time that adults of the destructive species of grasshoppers were available was so short (about three months) that it was necessary to limit the work. After a method was devised, toxicity tests of seven compounds were made upon two of the more abundant destructive species, the red-legged grasshopper, *Melanoplus femur-rubrum* (Deg.) and the differential grasshopper, *Melanoplus differentialis* (Thomas). A

[1]Journal Paper No. B36 of the Iowa Agricultural Experiment Station.

few tests not reported in this paper were made upon the large grasshopper, *Schistocerca lineata* (Scudder).

MATERIALS. The adult grasshoppers were captured with a sweep net and placed in cages where they were supplied with fresh field corn foliage until used. To insure that they would feed eagerly upon the poisoned bait, they were usually kept without food for three to fifteen hours before the experiment.

The poisoned bait consisted of wheat bran, cane molasses, a poisonous compound and water. The bran was a coarse, flaky product, largely free from shorts; the molasses was a commercial grade put up in tin cans for table use. Distilled water was used in all the bait preparations.

The following compounds were used as poisons in the baits: Arsenious oxide (99.89% As_2O_3); monosodium arsenite (NaH_2AsO_3); trisodium arsenite (Na_3AsO_3); Paris green [$(CuOAs_2O_3)_3.Cu(C_2H_3O_2)_2$],CuO 38.84%, As_2O_3 54.75%, water-soluble As_2O_3 3.00%; acid lead arsenate ($PbHAsO_4$) PbO 64.50%, As_2O_5 32.88%, water-soluble As_2O_5 0.22%; sodium fluosilicate (96.71% Na_2SiF_6); rotenone (tech.) 94.6% rotenone. The solutions of monosodium arsenite and trisodium arsenite were prepared from arsenious oxide C. P. and a quantitative solution of sodium hydroxide free from carbonates and silicates, and were kept in tightly stoppered bottles.[2] Each solution contained 37.875 grams of the respective arsenite per liter.

METHOD USED IN TOXICITY EXPERIMENTS. The administration of known doses of the toxic compounds to the grasshoppers was accomplished by allowing them to consume small quantities of the bait from a tared dish, the dish and the grasshopper being retained in a moist chamber during the feeding process to prevent loss of moisture, and thereby loss of weight, from the bait.

The mixture employed in the experiments was based upon the following widely used formula for home-mixed bait: Bran 100 pounds, arsenious oxide (or Paris green) 5 pounds, molasses 2 gallons, water 10 gallons. In order to prevent change in weight during the time the bait remained in the moist chamber, the proportion of water was increased by about one-third. With this addition, the mean loss of water in one hour was about 0.8 per cent, a quantity within the limits of error of the determinations. The bait mixture finally adopted contained bran 25 grams, poisonous ingredient 1.25 grams, molasses 5.8 grams, and water

[2]We are indebted to Dr. I. B. Johns, Jr., Department of Chemistry, Iowa State College, for the preparation of these solutions.

33 grams. The quantity of water was adjusted to compensate for variations in the quantity of the poisonous ingredient. Water and the sodium arsenite solutions were measured volumetrically on the basis of 1 cc. equals 1 gram. The density of the monosodium arsenite solution was 1.0383, that of the trisodium arsenite solution 1.0486. The baits were made up fresh for each day's experiments and placed in moist chambers before use. In the preparation of the bait care was taken to mix thoroughly all the ingredients.

The procedure was as follows: About 0.5 gram of the bait was placed in a small watch glass, quickly weighed on a chainomatic balance, and removed to a moist chamber. For this purpose bacterial culture dishes of 150 mm. outside diameter and 50 mm. depth were convenient. A grasshopper, previously weighed, was placed in the moist chamber near the food. When hungry, it usually began to feed in a few minutes and continued for 15 to 30 minutes if the bait contained no poison or was only mildly toxic. Feeding was accomplished generally without waste of bran particles; if, as sometimes happened, a small piece of the bran was dropped on the floor of the moist chamber, it was replaced in the watch glass by means of fine-pointed forceps. After the desired quantity of the bait was eaten, the watch glass and the bait were again quickly weighed. The difference between the original and final weights represents the quantity of the bait eaten by the grasshopper. This value multiplied by the per cent by weight of the poisonous compound in the bait furnishes the quantity of the toxic compound ingested. From this value and from the weight of the grasshopper, the quantity of toxic compound eaten in milligrams per gram of body weight was calculated. The dosage was varied by controlling the feeding time, and by utilizing baits with different concentrations of the toxic compound.

The grasshopper was then removed from the moist chamber to a small cylindrical wire cage, supplied with fresh corn foliage, and was observed at intervals until death or recovery. The criterion of death was the inability of the insect to move when the hind tarsus was pinched.

All experimental grasshoppers were accompanied by controls which were sometimes fed upon bran bait without poison, sometimes placed directly in a cage with fresh corn foliage. This slight difference in treatment had no observable effect upon them. Of the 188 individuals of *Melanoplus femur-rubrum* and 76 individuals of *M. differentialis* in the control series, about 9.5 per cent died during each of the first three survival periods, whereas about 71.5 per cent survived more than 96 hours, and are regarded as unaffected. There was little evidence of parasitism among the control insects or, for that matter, among those

which were fed the poisoned baits. A few were observed to contain dipterous larvae (Sarcophagids); and a small number were infested with nematodes. As the number of individuals dying in each survival period from causes other than poisoning was approximately equal and not excessively large, the mortality in the controls has been disregarded in calculating the dosages for the several toxic compounds.

RESULTS OF THE TOXICITY EXPERIMENTS. The results of the toxicity experiments with the baits containing the seven compounds are given in Table 1 and toxicity curves for five of them are plotted in Figure 71.

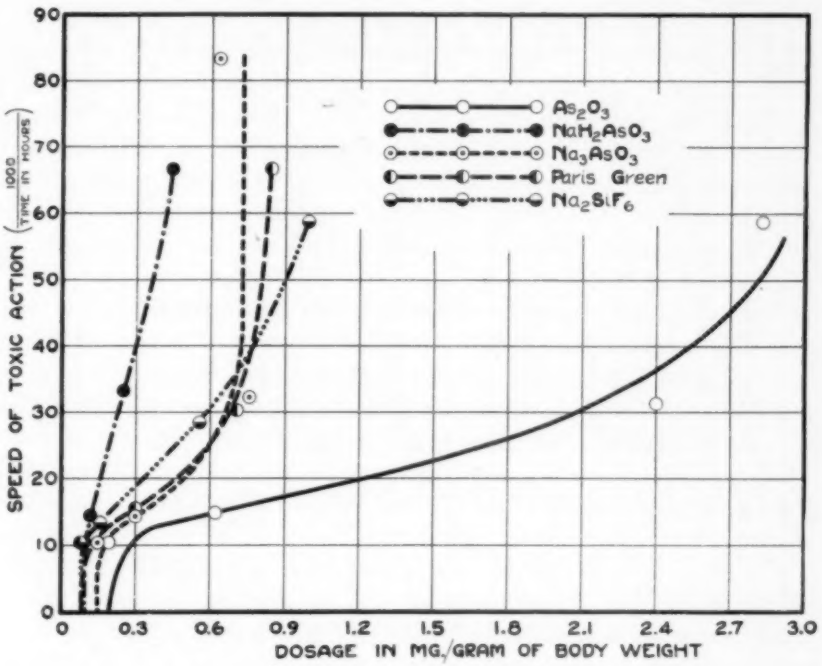

Fig. 71.—Relation between the dosage and the speed of toxic action of four arsenicals and sodium fluosilicate in bran bait. *Melanoplus femur-rubrum* was the test insect.

The dosages in milligrams per gram of body weight are collected into four groups, each group with its corresponding survival period. The grasshoppers with dosages falling in the third group survived a mean time of approximately sixty to seventy-five hours; those fed dosages which fall in the fourth group lived more than ninety-six hours and are considered to have recovered. In most cases the latter individuals were kept under observation for one hundred and fifty or more

TABLE 1. TOXICITY OF VARIOUS STOMACH POISONS TO ADULT GRASSHOPPERS

Compound	*Melanoplus femur-rubrum* (Deg.) No. of Individuals ♂s	♀s	Dose of Compound in mg./Gram Body Weight[1] Min.	Av.	Max.	Survival Period Hours Min.	Av.	Max.	M.L.D. Mg./gram body weight	*Melanoplus differentialis* (Thomas) No. of Individuals ♂s	♀s	Dose of Compound in mg./Gram Body Weight[2] Min.	Av.	Max.	Survival Period Hours Min.	Av.	Max.
Arsenious Oxide	8	12	.44	2.83	5.10	10	17	24		7	1	1.38	2.29	3.02	10	17	24
	4	11	.33	2.40	5.36	25	32	48		7	4	.85	2.03	3.82	25	34	48
	1	5	.07	.62	.91	49	67	96		—	1	—	3.79	—	—	58	—
	1	10	.09	.19	.52		Recovered		0.36	1	2	.30	.34	.38		Recovered	
Monosodium Arsenite	13	10	.04	.44	1.25	6	15	24		6	2	.20	.51	.88	3	14	24
	11	9	.05	.25	.80	25	30	48		–	–	—	—	—	—	—	—
	1	6	.05	.12	.21	49	69	96		–	–	—	—	—	—	—	—
	2	8	.02	.09	.22		Recovered		0.10(.16)	–	–	—	—	—	—	—	—
Trisodium Arsenite	4	9	.18	.63	1.32	2	12	24		3	4	.26	.49	.67	7	14	24
	2	2	.26	.76	1.46	25	31	48		–	1	—	.30	—	49	70	96
	–	8	.09	.30	.78	49	70	96		–	2	.02	.04	.05		Recovered	
	–	4	.06	.15	.31		Recovered		0.22(.16)	–	–	—	—	—	—	—	—
Paris Green	15	10	.06	.84	2.83	4	15	24		5	4	.33	1.17	1.97	9	17	24
	3	10	.10	.71	1.68	25	33	48		1	3	.06	.50	1.40	25	33	48
	1	3	.09	.30	.75	49	64	96		–	4	.01	.04	.09		Recovered	
	1	6	.04	.08	.15		Recovered		0.19(.16)	–	–	—	—	—	—	—	—
Acid Lead Arsenate	5	1	1.21	2.81	3.97	48	80	96		3	2	.64	1.39	2.02	15	44	96
	2	5	3.30	4.48	5.65		Recovered		?	3	4	1.31	2.65	3.96		Recovered	
Sodium Fluosilicate	17	16	.15	.99	2.78	9	17	24		11	7	.11	1.10	2.90	12	18	24
	4	3	.11	.57	1.66	25	35	48		2	3	.90	1.69	3.06	25	29	48
	2	1	.09	.16	.29	49	74	96		–	1	—	.31	—	—	75	—
	4	4	.04	.08	.16		Recovered		0.12(.16)	1	1	.07	.11	.15		Recovered	
Rotenone	–	1	—	.54	—	—	33	—		–	1	—	.52	—	—	9	—
	–	5	1.92	2.92	4.12		Recovered		?	1	1	1.47	1.78	2.09	49	62	96
										–	1	—	1.60	—		Recovered	

	Min.	Av.	Max.
[1]Weight in grams of 123 ♂s	0.160	0.283	0.384
Weight in grams of 172 ♀s	.184	.369	.593

	Min.	Av.	Max.
[2]Weight in grams of 66 ♂s	0.436	0.854	1.232
Weight in grams of 59 ♀s	.812	1.428	2.607

hours. As the third group is represented by dosages that required the longest time to kill and the dosages of the fourth group essentially permitted recovery, there should be a point somewhere between the two groups that would represent the true median lethal dose (M.L.D.), i.e., the dose at which half the population is killed and half survives. If the means of the dosages of the third and fourth groups are statistically alike, then the simple arithmetical average of these means will furnish a good estimate of the M.L.D. All comparisons of means have been made according to Fisher's method[3] for the comparisons of means of small samples. The results discussed below are based largely upon the experiments with the more abundant *Melanoplus femur-rubrum*.[4]

Arsenious oxide was the least toxic, except acid lead arsenate, of the five arsenical compounds. The M.L.D., calculated from the means of the third and fourth dosage groups, is 0.36 mg./gram of body weight. It is probable that this figure is too high as there is a significant difference between the means, 0.62 and 0.19, from which it is derived. It is, however, the best estimate obtainable from these data.

Solutions containing the stoichiometric proportions of arsenious oxide and sodium hydroxide to form monosodium arsenite and trisodium arsenite were used in the baits to determine whether differences in their toxic activity could be established. Both solutions were strongly alkaline, indicating that extensive hydrolysis had taken place. They probably contained the ions, Na, OH, H_2AsO_3, $HAsO_3$, AsO_3 and possibly AsO_2,[5] besides molecular H_3AsO_3 and perhaps $HAsO_2$. The bran-molasses bait is itself slightly acid (pH 5.85) before the arsenite solution is added, and when the two are mixed, a reduction in pH occurs, changing the proportion of molecules and ions.

The estimated M.L.D. for monosodium arsenite is 0.10 mg./gram, or about one-half that obtained for trisodium arsenite. Compared statistically, the M.L.Ds. show no significant difference; at all shorter survival periods, however, the mean toxic dosages of monosodium arsenite appear to be smaller than those of trisodium arsenite and of the other compounds tested. The interpretation of this difference is not yet clear.

[3]Fisher, R. A. Statistical Methods for Research Workers. 2nd Ed. XI + 269 p. London, 1928.

[4]Each specimen of apparent *Melanoplus femur-rubrum* used in these experiments was retained and identified by Dr. H. H. Knight, Department of Zoology and Entomology, Iowa State College, for which kindness the writers are obliged. All but six of these grasshoppers proved to be typical *M. femur-rubrum* (Deg.).

[5]Anderson, E., and Story, L. G. Studies on Certain Physical Properties of Arsenic Trioxide in Water Solution. J. Amer. Chem. Soc. 45, No. 5, 1102–1105, 1923.

Toxicity figures for sodium arsenite in bran baits for *Melanoplus femur-rubrum* have been given by Moore[6] and Granovsky,[7] but they are derived from experiments of a different nature than those described above and cannot easily be compared. Campbell[8] noted that the adult *M. femur-rubrum* "was very much less susceptible to arsenic, administered either by mouth or by injection, than is the silkworm." He fed neutral solutions of sodium arsenite to silkworm larvae of various ages, and observed that the M.L.D. varied from about 0.0075 mg. As/gram for the second instar to about 0.0125 mg. As/gram for the fifth instar. For the larvae of the lepidopterous insects, *Datana ministra* (Dru.) and *Malacosoma americana* (Fab.), Campbell[9] found that the M.L.D. of a sodium arsenite solution (pH > 10), administered orally, was approximately 0.02 mg. As/gram. The M.L.D. of monosodium arsenite in bran bait for *M. femur-rubrum* is about 0.05 mg. As/gram, a figure considerably higher than the M.L.D. for these lepidopterous larvae.

The toxicity of Paris green to *M. femur-rubrum* resembles that of the sodium arsenites and of sodium fluosilicate both with respect to the M.L.D., which cannot be separated statistically from the M.L.D. of these compounds, and the general course of the toxicity curve. In a previous communication,[10] it was shown that the larva of *Leptinotarsa decemlineata* (Say) succumbs in about 6 hours to a mean dose of about 0.37 mg./gram of Paris green and that the M.L.D. is certainly less than 0.10 mg./gram. The M.L.D. for *M. femur-rubrum* is probably twice as large as that for the *Leptinotarsa* larva.

It has been known for some time that acid lead arsenate is a much less satisfactory poison for grasshopper baits than arsenious oxide or Paris green. In spite of this, considerable quantities of it were used in locally prepared baits during the past summer in Iowa, always, so far as could be ascertained with very poor results. Both species of grasshoppers recovered or died slowly after consuming large quantities of this com-

[6]Moore, W. Spreading and Adherence of Arsenical Sprays. Minn. Agric. Expt. Sta. Tech. Bull. 2, 50 p., 1921.

[7]Granovsky, A. A. The Efficiency of Sawdust Bait in the Control of Grasshoppers. This Journal, 19, No. 2, 211–218, 1926.

[8]Campbell, F. L. Relative Susceptibility of Arsenic in Successive Instars of the Silkworm. J. Gen. Physiol. 9, No. 6, 727–733, 1926.

[9]Campbell, F. L. The Practicability of Quantitative Toxicological Investigations on Mandibulate Insects. J. Agric. Research, 32, No. 4, 359–366, 1926.

[10]Richardson, C. H., and Haas, L. E. The Toxicity of Acid Lead Arsenate to the Larva of the Colorado Potato Beetle. This Journal, 24, No. 3, 732–736, 1931.

pound. The M.L.D. is at least thirty times that found by Campbell and Filmer[11] for the fourth instar silkworm.

It was rather surprising to find the M.L.D. of sodium fluosilicate indistinguishable from that of the arsenites though so far outside the range of toxicity values obtained for acid lead arsenate. Accepting 0.16 mg./gram as the M.L.D. of sodium fluosilicate and > 3.0 mg./gram for acid lead arsenate, the former compound has more than nineteen times the toxicity of acid lead arsenate. For the silkworm, Campbell[12] obtained the same M.L.D. (0.090) for both compounds, but comparison of the ratios of areas of toxicity curves, indicated that sodium fluosilicate was slightly less than twice as toxic as acid lead arsenate. The values are interesting from the standpoint of the wide difference that may occur in the relative toxicity of two compounds to diverse species of insects.

Only a few tests were made with rotenone for it was soon evident that large doses of this compound either did not harm the grasshoppers at all, or acted slowly upon them. The possibility that certain ingredients of the bran bait might react with rotenone to reduce its toxicity, led to some tests by a leaf sandwich method previously described.[10] Corn leaf sandwiches containing rotenone in starch paste were fed, immediately after preparation, to adults of *M. femur-rubrum*. Doses of about 4.5 to 7.0 mg./gram were fatal in 30 to 73 hours; recovery occurred from doses of 0.7 to about 1.3 mg./gram. Shepard and Campbell[13] find that rotenone is very highly toxic to the silkworm, the M.L.D. being 0.003 mg./gram, i.e., thirty times as toxic as acid lead arsenate to this insect. They suggest that the wide difference in the degree of toxicity of rotenone to insects may depend upon the physiological characteristics of the species and its food.

EFFECT OF THE POISON ON THE QUANTITY OF BRAN BAIT EATEN. In a previous communication[10] it was noted that the quantity of food ingested by the larva of the Colorado potato beetle, *Leptinotarsa decemlineata*, was greatly influenced by the presence of acid lead arsenate and

[11]Campbell, F. L., and Filmer, R. S. A Quantitative Method of Estimating the Relative Toxicity of Stomach Poison Insecticides. IV. Internat. Congress Ent., Ithaca 1928, 2, 523–533, 1929.

[12]Campbell, F. L. A Comparison of Four Methods for Estimating the Relative Toxicity of Stomach Poison Insecticides. This Journal, 23, No. 2, 357–370, 1930.

[13]Shepard, H. H., and Campbell, F. L. The Relative Toxicity of Rotenone and Some Related Compounds as Stomach Poisons. This Journal 25, No. 1, 142–144, 1932.

TABLE 2. QUANTITY OF BRAN BAIT EATEN BY GRASSHOPPERS WHICH WERE ALLOWED TO FEED *Ad Libitum*

Material	*Melanoplus femur-rubrum* (Deg.) Concentration of Poison in Bait, %	Number of Individuals	Quantity of Bait Eaten, Grams/Gram Body Wt. Min.	Av.	Max.	Quantity of Poison mg./Gram Body Wt. in Av. Wt. of Bait Consumed	Survival Period in Hours at Dose Consumed	*Melanoplus differentialis* (Thomas) Concentration of Poison in Bait, %	Number of Individuals	Quantity of Bait Eaten Grams/Gram Body Wt. Min.	Av.	Max.	Quantity of Poison mg./Gram Body Wt. in Av. Wt. of Bait Consumed	Survival Period in Hours at Dose Consumed
Bran bait without poison...	—	34	.08	.16	.25	—	—	—	17	.01	.13	.24	—	—
Bait plus Arsenious Oxide....	1.85	26	.09	.18	.27	3.33	10–48	1.85	21	.06	.12	.21	2.22	10–48
Bait plus Monosodium Arsenite....	1.48	14	.02	.05	.09	.74	6–24	1.48	8	.01	.04	.06	.59	3–24
Bait plus Trisodium Arsenite..	1.84	17	.01	.04	.08	.74	2–24	1.84	8	.01	.02	.04	.37	7–24
Bait plus Paris Green...	1.85	26	.01	.06	.15	1.11	4–24	1.85	11	.01	.06	.17	1.11	9–24
Bait plus Sodium Fluosilicate.....	1.85	12	.05	.11	.15	2.04	9–24	1.85	22	.01	.07	.17	1.30	12–48
Bait plus Acid Lead Arsenate	1.85	13	.06	.20	.28	3.70	49–96 or recovered	1.85	12	.04	.12	.21	2.22	Recovered
Bait plus Rotenone	1.76	6	.03	.14	.22	2.46	Recovered	—	—	—	—	—	—	—

Paris green. Observations made upon these larvae while feeding indicated that the toxic action was initiated within a few minutes after the first few morsels of poisoned food were swallowed, that the time of feeding was shortened and that the quantity of ingested food was decreased by incipient poisoning with its correlative loss of appetite. Experiments were undertaken to determine whether the same phenomenon could be observed in grasshoppers. Adult grasshoppers were allowed to feed *ad libitum* on bran bait without poison, and upon baits which contained the several poisons, being removed from the moist chamber only when they had become satiated. The results, expressed as the quantity of food eaten in grams per gram of body weight, are shown in Table 2.

In thirty-four feedings, the adults of *M. femur-rubrum* consumed, before they ceased to eat, a mean of 0.16 gram/gram of the bran, molasses and water mixture. The weighted mean weight of this group of thirty-four individuals, based upon the means of the sexes given in Table 1, is 0.331 gram. The consumption of the bait without poison by a grasshopper of this weight is 0.053 gram, or 16 per cent of its weight.

The mean bait consumption for the mixtures containing arsenious oxide, and rotenone have been compared by the method for small samples[3] with the mean for bran bait without poison. In each case the difference is at most of doubtful statistical significance (p=approximately 0.3). The mean for the mixtures which contained acid lead arsenate is larger and the difference is significant, but is probably without biological importance. The means for the baits which contained sodium fluosilicate, Paris green, monosodium arsenite and trisodium arsenite are each smaller and statistically distinct from the mean for the normal bran bait. The value for the bait which contained sodium fluosilicate lies between that for normal bait and baits containing Paris green. If undisturbed, the insects consumed a mean quantity of bait containing these four active poisons which was less than that of the normal bait but was still sufficient to kill within twenty-four hours. When, however, the mean bait consumption was equal to or greater than that of the normal bait, as usually was the case with the less active poisons, the survival time was longer or recovery followed. There was no visible indication of olfactory or gustatory repellence.

The quantity of data available for *M. differentialis* is smaller but it tells a similar story. The mean consumption of bran mixture without poison was 0.13 gram/gram, a quantity smaller (and probably significantly so) than the value obtained for *M. femur-rubrum*. From the

weighted mean weight of 1.090 grams for the seventeen individuals, it was found that a hungry *M. differentialis* consumes about 0.14 gram of bran bait without poison, or about 13 per cent of its body weight. The mean consumption of bait containing acid lead arsenate is equivalent to that for bran bait alone; the consumption of bait containing sodium fluosilicate is somewhat less though the difference is statistically not very significant (p=0.1–0.2). The data for the other bait mixtures agree closely with the data from *M. femur-rubrum*.

THE RELATION OF RESPIRATORY METABOLISM OF INSECTS TO THEIR SUSCEPTIBILITY TO FUMIGANTS

By R. T. Cotton, *Senior Entomologist, Bureau of Entomology, United States Department of Agriculture*

Abstract

The susceptibility of an insect to a fumigant varies with the rate of respiratory metabolism. Certain factors increase the rate of metabolism; others decrease it and automatically increase or decrease the susceptibility of the insect. Of the known factors that increase the suceptibility of the insect to a fumigant, the three most important are: An increase in temperature; an increase in the carbon dioxide content of the fumigation chamber; and a decrease in the oxygen content of the fumigation chamber.

"There can be no doubt that within a given species or organism a general relation exists between metabolic condition and susceptibility to a given narcotic. Differences in metabolic condition do not exist independently of differences in condition of the colloid substratum and whether the narcotic affects primarily the substratum or certain of the chemical reactions, the susceptibility of the organism or part to its action must differ as the conditions which determine or are associated with metabolic activity differ. * * * In concentrations in which death occurs at times varying from a few minutes to a few hours and when complicating factors are absent, the susceptibility varies directly with the general metabolic rate, conditions which increase metabolic activity increase susceptibility and vice versa."

Although the preceding statement by Child (4, p. 71, 72) was not made with particular reference to insects, it does apply equally well to them. In insects, metabolic activity is distinctly influenced by environmental factors. Certain factors increase the rate of metabolism; others decrease it and automatically increase or decrease the susceptibility of insects to the action of fumigants. Since in many cases the environmental

conditions can be controlled, the degree of success or failure of a fumigation will depend upon a knowledge of the reaction of insects to these conditions. In the following pages experimental evidence is presented

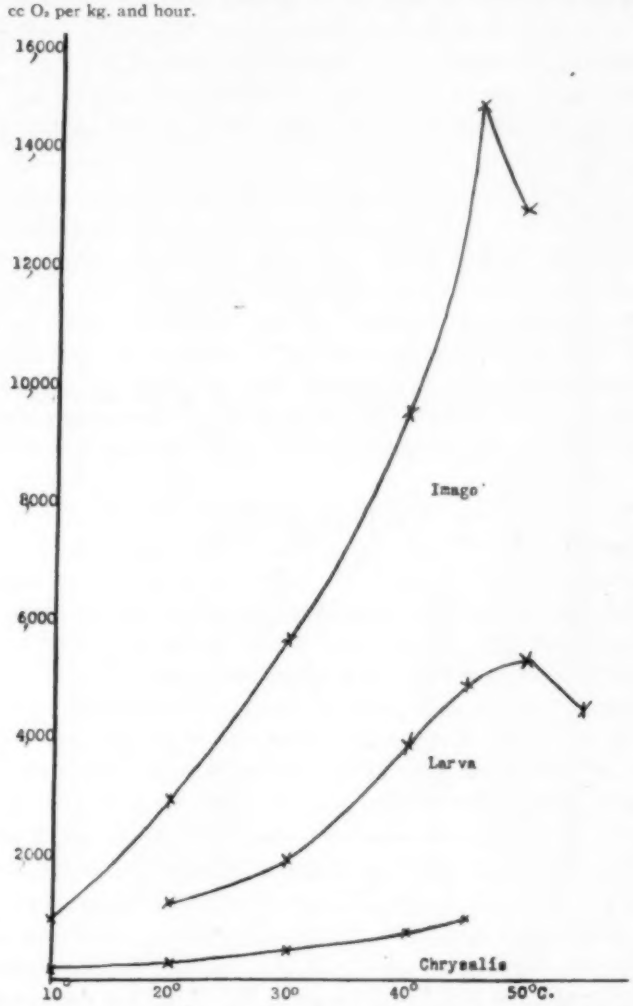

Fig. 72.—The respiratory exchange of flies in the adult, larval, and pupal stages at various temperatures. (Battelli and Stern.)

to show the effect of differences in the rate of metabolism on the susceptibility of insects to the action of fumigants and of certain factors influencing the rate of metabolism.

RELATIVE SUSCEPTIBILITY OF DIFFERENT STAGES OF AN INSECT TO FUMIGANTS. Several workers have shown that the rate of metabolism varies with the stage of an insect's development. In most species the adult, or imago, has the highest rate, followed in order by the larva and the pupa. This difference is admirably shown in Figure 72, drafted from data obtained in the researches of Battelli and Stern (2).

As there is this marked difference in the metabolic rates of the various life-history stages, we should expect that, other conditions being equal, the stages would show a corresponding difference in susceptibility to fumigants. The following tests with adults, larvae, and pupae of the confused flour beetle (*Tribolium confusum* Duv.) and the Mediterranean flour moth (*Ephestia kuehniella* Zell.) have shown that this is true.

Test lots, each consisting of 50 adults, 25 larvae, and 25 pupae of *Tribolium confusum* were placed together in 6-liter glass flasks and fumigated for 3 hours, at a temperature of 75° F. with varying quantities of carbon disulphide. The adults were all killed with a dosage of 125 mg per liter. To obtain a 100 per cent kill of the larvae a dosage of 163 mg per liter was required and of the pupae a dosage of 314 mg per liter.

Similarly, test lots of adults, larvae, and pupae of *Ephestia kuehniella* were fumigated with different dosages of carbon disulphide for 3 hours at a temperature of 75° F. with the following results: A dosage of 50 mg per liter was required for a 100 per cent kill of the pupae; a dosage of 25 mg per liter for a 100 per cent kill of the larvae; and a dosage of 6.25 mg per liter for a 100 per cent kill of the adults. (Fig. 73.)

DIFFERENCES IN SUSCEPTIBILITY AMONG SPECIES OF THE SAME GENUS. O. M. Helff (9), in studying the rate of oxygen consumption in larvae of five species of Amblystoma found that the metabolic rates of the different species were widely divergent, the mean oxygen consumption of 10 larvae of *A. microstomium* Cope being 200 per cent higher than tion of 10 larvae of *A. tigrinum* Green. The same condition doubtless holds true for different species of other genera and may account for the fact that different species in the same genera vary markedly in their susceptibility to fumigants. Adults of the rice weevil (*Sitophilus oryza* L.), for example, are killed in 3 hours at 75° F. with a dosage of 9 mg of ethylene oxide per liter, whereas to kill adults of the closely allied granary weevil (*S. granarius* L.) under the same conditions a dosage of 13.5 mg of ethylene oxide per liter is required. Similarly, a dosage of 33.5 mg of carbon disulphide per liter gives a 100 per cent kill of adults of the rice weevil in 3 hours at 75° F., whereas a dosage of 50.25 mg of

carbon disulphide per liter is required to kill 100 per cent of granary-weevil adults under the same conditions. In each case it required a 50 per cent higher dosage of fumigant to kill the granary weevil than the

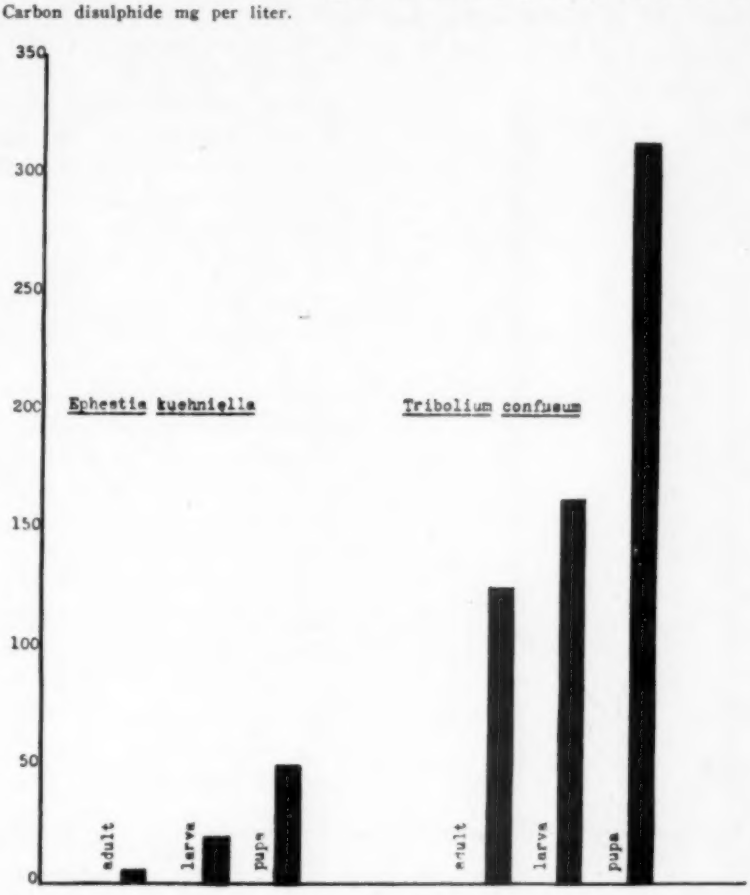

Fig. 73.—Varying quantities of carbon disulphide giving 100 per cent kill of adults, larvae and pupae of *Tribolium confusum* and *Ephestia kuehniella* in 3 hours at 75° F.

rice weevil. The rice weevil is much more active by nature than is the granary weevil and probably has a higher rate of metabolism.

THE EFFECT OF TEMPERATURE ON THE SUSCEPTIBILITY OF INSECTS TO FUMIGANTS. That insects are more susceptible to fumigants at higher temperatures than at low temperatures is well known to entomologists. The rate of absorption and the volatility of a fumigant as influenced by

changes in temperature are factors that influence the toxicity of a given quantity of a fumigant, but the greatest factor is the change in the rate of metabolic activity of the insect itself.

Krogh (11, p, 95–97) states that "the velocity of the catabolic reactions increases in all animals (including insects) with rising tempera-

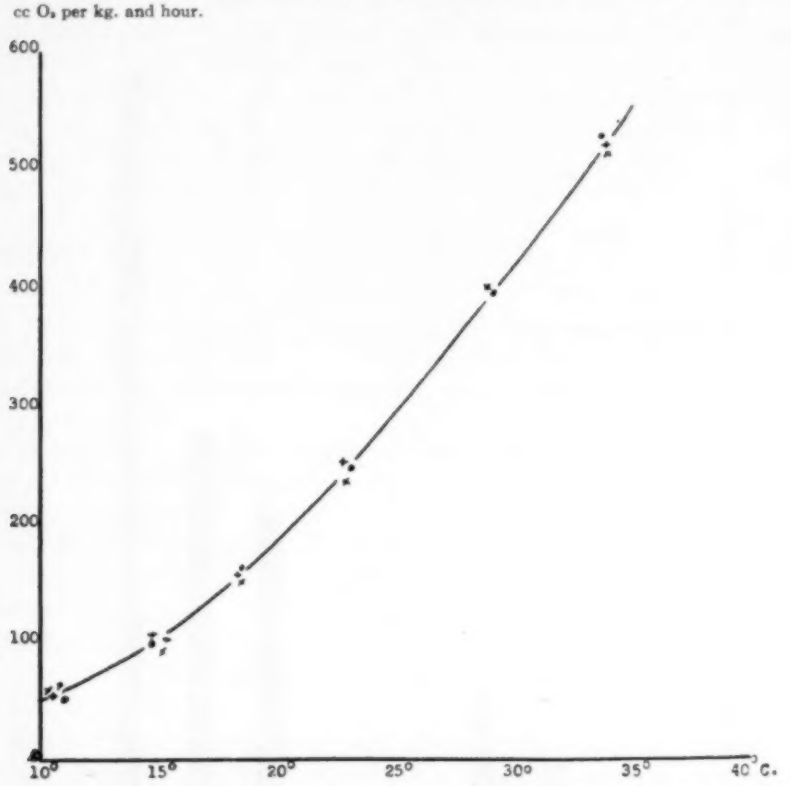

Fig. 74.—The effect of temperature on the metabolism of pupae of *Tenebrio molitor*. (After Krogh.)

tures up to a maximum at and above which the temperature has a deleterious effect upon the organism." This effect is clearly shown in Figure 72, which gives the respiratory exchange of flies at various temperatures, and in Figure 74, which shows the rate of metabolism of the pupa of the yellow meal worm (*Tenebrio molitor* L.) at different temperatures as determined by Krogh (11, p. 97).

Experiments were conducted with adults of *Tribolium confusum* at temperatures of 50°, 70°, and 80° F. At each temperature test lots of

50 individuals each were fumigated for 3-hour periods in 6-liter glass flasks with varying quantities of ethylene oxide. Ethylene oxide was used because it has a boiling point of about 50° F. and vaporizes readily at the various temperatures used. In the first experiments conducted, the insects, prior to fumigation, were kept for several days at the temperatures at which they were to be fumigated, in order that the normal respiratory rate for that particular temperature would be attained before the fumigation began. The results of these tests are shown in Figure 75.

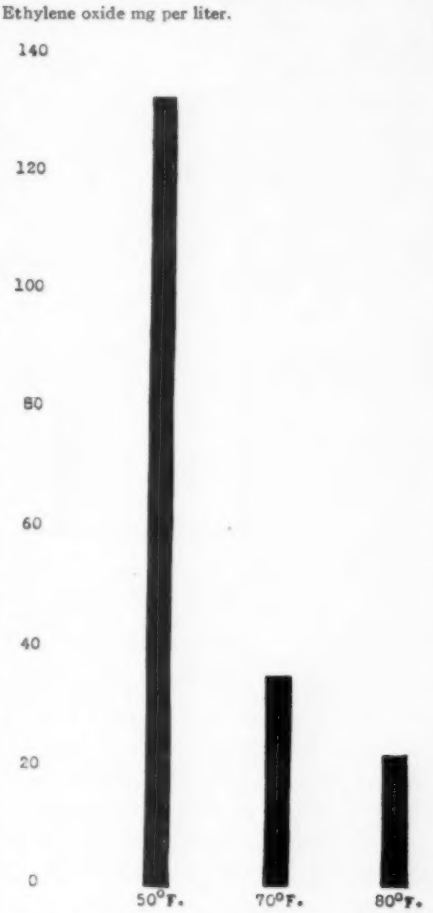

Fig. 75.—Dosage of ethylene oxide required to give 100 per cent kill of adults of *Tribolium confusum* at 50°, 70°, and 80° F. in 3 hours.

At a temperature of 80° F. the dosage of ethylene oxide required to kill 100 per cent of *Tribolium confusum* adults in 3 hours was 22 mg per liter; at 70° F., 35.5 mg was required; and at 50° F., 133 mg per liter, or six times the amount required at 80° F. That this increase in susceptibility of the insect with the increase in temperature was due largely to the increase in the rate of metabolism induced by the rise in temperature is shown by the following experiments:

The tests at 50° F. were repeated, but in this experiment half the insects had been kept at 50° F. for several days prior to the tests, and the other half had been kept at room temperature, or 75° F. To effect a 100 per cent kill of the latter required a dosage of only 53 mg per liter, as compared with the dosage of 133 mg per liter required to kill the insects that had been held at 50° F. (Fig. 76.)

Similarly, the tests made at 80° F. were repeated, half the insects having been kept at 50° F. for several days prior to the fumigation and the other half at 80° F. A dosage of 40 mg per liter was required to kill 100

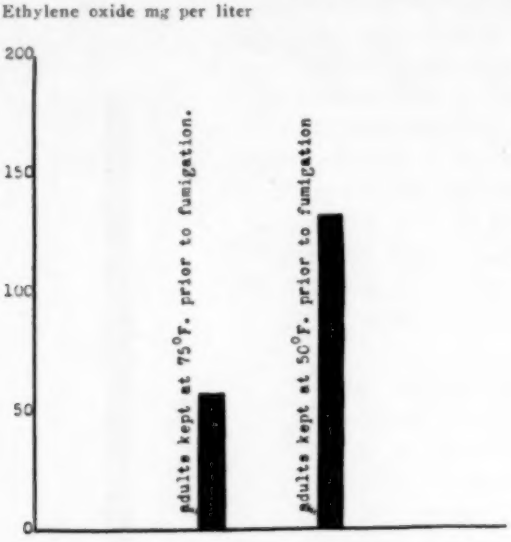

Fig. 76.—Variation in dosage of ethylene oxide required to give 100 per cent kill in 3 hours at 50° F. of adults of *Tribolium confusum* kept at different temperatures prior to fumigation.

per cent of the insects previously kept at 50°, whereas only 22 mg per liter was required to kill those kept at 80°. (Fig. 77.)

In these last two sets of experiments the initial difference in the metabolic rate of the various lots of insects was responsible for the great difference in the quantity of fumigant needed to kill them.

In commercial fumigation work it frequently happens that commodities having a comparatively low temperature need to be fumigated. These commodities are often placed in vacuum tanks or fumgation vaults that have been heated to temperatures of 75° or 85° F., with the expectation that the heat of the fumigation chamber will cause the infesting insects to be more easily killed.

The foregoing experiments show, however, that insects that have been kept at low temperatures do not respond readily to sudden changes in temperature, but retain for some time an added resistance to fumigants, this resistance being unaffected by the temperature of the fumigation chamber. Furthermore, as heat penetrates most commodities slowly the

infesting insects would be unaffected by the heat of the fumigation chamber until it had thoroughly penetrated the materials. Hence, all commodities taken from cool or cold storage should, if possible, be allowed to warm up to at least 70° F. before being fumigated.

THE EFFECT OF OXYGEN DEFICIENCY ON THE SUSCEPTIBILITY OF INSECTS TO FUMIGANTS. A deficiency in the oxygen content of air has an immediate effect upon the respiration of the animal that breathes it.

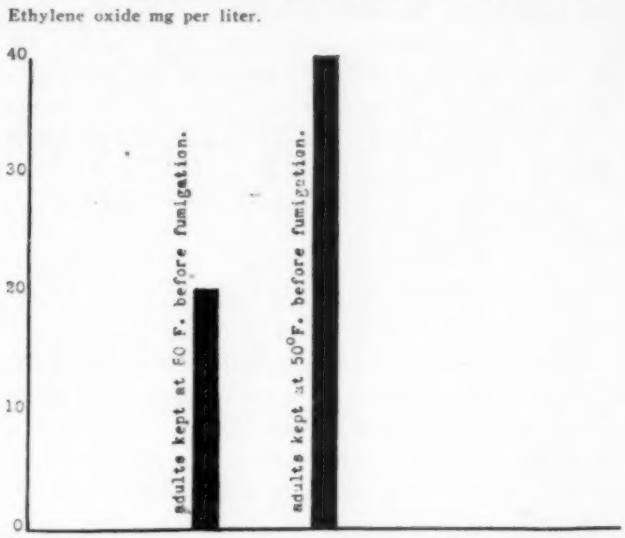

Fig. 77.—Variation in dosage of ethylene oxide required to give 100 per cent kill in 3 hours at 80° F. of adults of *Tribolium confusum* kept at different temperatures prior to fumigation.

In human beings, according to Henderson and Haggard (10, p. 37), the effect of a progressive decrease of the oxygen in the air does not become marked until the partial pressure has fallen from the normal of 21 per cent to about 13 per cent of an atmosphere and the oxygen in the air of the lungs is reduced to about 8 or 9 per cent. The inhalation of an inert gas with little or no oxygen induces a great increase in the rate of respiration.

A few investigators have observed similar effects in the respiration of insects. Babak and Foustka (1) concluded that lack of oxygen in some way causes stimuli promoting respiratory movements in dragonfly larvae. They found that if the water were poor in oxygen a typical dyspnea appeared. Similarly Buddenbrock and Rohr (3) observed that when the oxygen content of air was reduced to 3 or 4 per cent the respiratory

movements of the Indian walking stick (*Dixippus morosus* Brunn.), ordinarily very slight, became energetic.

In order to test the effect of oxygen deficiency on the susceptibility of insects to fumigants, experiments were conducted with various species of insects in a vacuum tank in which the the oxygen content of the atmosphere could be readily regulated. For example, since the air normally contains 21 per cent of oxygen, the drawing of a 20-inch vacuum is equivalent to reducing the oxygen content of the fumigation tank to approximately 7 per cent of an atmosphere, at a pressure of 760 mm. By drawing in the fumigant without further admission of air and holding the resulting vacuum throughout the exposure, the concentration of oxygen in the tank would remain constant during the experiment.

In the first experiments conducted, adults of *Tribolium confusum* in lots of 50 were subjected to a constant dosage of ethylene dichloride at a constant temperature of 86° F. and a constant exposure of 30 minutes in a vacuum tank of 21.76-liter capacity. The only variable was the oxygen content of the atmosphere in the vacuum tank, this being varied by drawing any desired vacuum. It was found that when the oxygen content of the atmosphere in the fumigation chamber was reduced below 7 per cent it had a marked effect upon the respiration of the insects and rendered them more susceptible to the effect of the fumigant. To a certain extent, the more the oxygen content was reduced the greater the effect upon the insect. This effect is well illustrated by the data in Table 1.

TABLE 1. EFFECT OF LACK OF OXYGEN ON THE SUSCEPTIBILITY OF *Tribolium confusum* ADULTS TO THE VAPORS OF ETHYLENE DICHLORIDE

Vacuum drawn and held	Oxygen in atmosphere of fumigation tank[1]	Dosage of ethylene dichloride	Kill after 30 minutes exposure
Inches	*Per cent*	*Milligrams per liter*	*Per cent*
5	17.5	75	0
10	14.0	75	0
15	10.5	75	0
17	9.1	75	0
18	8.4	75	0
19	7.7	75	0
20	7.0	75	10
21	6.3	75	10
22	5.6	75	15
23	4.9	75	45
24	4.2	75	45
25	3.5	75	50
26	2.8	75	85
27	2.1	75	100
28	1.4	75	100
29	.7	75	100

[1]Partial pressure based on atmospheric pressure as 100 per cent.

In order to determine whether other insects than *Tribolium confusum* were affected in the same manner, whether or not the immature stages of insects were similarly affected, and whether other gases than ethylene dichloride would show a simlar increase in toxicity under these conditions, additional experiments were conducted.

Fumigation tests were made with eggs and larvae of *Ephestia kuehniella*, pupae of *Tribolium confusum*, and adults of *Sitophilus oryza*. All experiments were made in a vacuum tank of 21.76-liter capacity, at a constant temperature of 86° F., and with a constant exposure of 30 minutes. The dosage required to give a 100 per cent kill was determined, first by drawing a vacuum of 29 inches and breaking it with fumigant and air down to 5 inches; and second, by drawing a vacuum of 29 inches, admitting the fumigant without air, and holding the resulting vacuum throughout the exposure. Drawing a 29-inch vacuum and holding it without further admission of air is equivalent to reducing the oxygen content of the fumigation chamber to approximately 0.7 per cent of an atmosphere at a pressure of 760 mm. The results obtained in these experiments are given in Table 2.

TABLE 2. EFFECT OF LACK OF OXYGEN ON SUSCEPTIBILITY OF INSECTS TO FUMIGANTS

Insect	Stage	Fumigant	Vacuum held *Inches*	Dosage giving 100 per cent kill in 30 minutes *Milligrams per liter*
Sitophilus oryza	adult	Ethylene oxide	0	48
Sitophilus oryza	adult	Ethylene oxide	29	24
Sitophilus oryza	adult	Methyl chloroacetate	0	17
Sitophilus oryza	adult	Methyl chloroacetate	29	8.5
Ephestia kuehniella	larva	Ethylene oxide	0	80
Ephestia kuehniella	larva	Ethylene oxide	29	35
Ephestia kuehniella	egg	Carbon disulphide	0	*502
Ephestia kuehniella	egg	Carbon disulphide	29	*502
Tribolium confusum	pupa	Ethylene oxide	0	141
Tribolium confusum	pupa	Ethylene oxide	29	22

*Exposure 1 hour.

The data given in Table 2 indicate that probably all species are affected in the same way by oxygen deficiency, though possibly not in the same degree; that larval and pupal stages, but not the egg stage, are similarly affected; and that other gases than ethylene dichloride show an apparent increase in toxicity when used in combination with oxygen deficiency. That oxygen deficiency, and not the low pressure occasioned by holding a high vacuum, is the factor affecting the insects, is shown by a later experiment, the data of which are given in Table 4. In this ex-

periment the oxygen deficiency was obtained by drawing a vacuum of 29 inches. This vacuum was then reduced with carbon dioxide (30 pounds per 1000 cubic feet) to 20.8 inches. At this vacuum the factor of oxygen deficiency was highly effective, although, as shown in Table 1, the drawing and holding of a vacuum of 21 inches has but little effect upon insects.

The effect of oxygen deficiency in rendering insects more susceptible to the effects of fumigants can be used to advantage in commercial vacuum fumigation work If a vacuum of from 27 to 29 inches is drawn and the fumigant admitted to the tank without further admission of air, and the resulting vacuum held for the entire length of exposure, a given quantity of fumigant will be much more effective than if the vacuum is broken with fumigant and air to near zero. In California it is customary when inflammable fumigants are used, to reduce the vacuum with an inert gas, such as carbon dioxide or nitrogen. Although such gases are used primarily to reduce the fire hazard, they also serve to exclude oxygen from the tank.

Experiments conducted with the vacuum tank filled with highly absorptive foodstuffs indicate that the principle holds true whether or not the vacuum tank is filled.

THE EFFECT OF CARBON DIOXIDE ON THE SUSCEPTIBILITY OF INSECTS TO FUMIGANTS. Carbon dioxide is a specific stimulus to the respiratory center in mammals. That it also affects the respiration of insects in a similar manner was observed by Hazelhoff in 1926 (7) during the course of his studies on the regulation of respiration in insects. In an article published in 1928 (8) he states that the cockroach, "*Periplaneta americana* [L.] e.g. displays no respiratory movements when at rest (at room temperature) and its tracheal valves are nearly closed; when the animal is brought into an atmosphere containing 2 or 3 per cent carbon dioxide, the spiracles open immediately, thus allowing a more rapid diffusion of the respiratory gases. When the carbon dioxide pressure is raised to about 7 or 10 per cent or more, ordinary respiratory movements of the abdomen appear. The width of the spiracle opening turned out to be regulated normally by the amount of carbon dioxide pressure in the immediate neighborhood of the spiracles."

He suggested that the penetration of hydrocyanic-acid gas and other gases into the tracheal system might be accelerated and their insecticidal action thereby increased by the application of a small quantity of carbon dioxide.

Curiously enough the insecticidal action of hydrocyanic-acid gas[1] is not increased by the addition of carbon dioxide, although its mixture with other gases causes a marked increase in their toxicity to insects. Cotton and Young in 1929 (6) published a brief account of their observations on the effect of mixing carbon dioxide with other fumigants. They found that adults of *Tribolium confusum* and *Sitophilus oryza* were much more susceptible to the vapors of ethylene dichloride, methyl chloroacetate, carbon disulphide, chloropicrin, and ethylene oxide when these substances were used in combination with small quantities of carbon dioxide.

Additional experimental work indicates that the increase in the rate of metabolism induced by increased concentrations of carbon dioxide affects not only the adult insects, but also their larval and pupal stages. For example, pupae of *Tribolium confusum* fumigated for 30 minutes at 86° F. required 141 mg of ethylene oxide per liter to give a 100 per cent kill; but when carbon dioxide was added at the rate of 30 pounds per 1,000 cu. ft. of space a dosage of only 62 mg of ethylene oxide per liter was required for a 100 per cent kill. The susceptibility of the egg stage to fumigants is not affected by the addition of carbon dioxide to the fumigation chamber.

In studying the effect of mixing carbon dioxide with other gases, it was noticed that the quantity of carbon dioxide needed to give the maximum insecticidal effect varied with the gas used. The maximum insecticidal effect with carbon disulphide was obtained in an atmosphere containing approximately 15 pounds of carbon dioxide per 1,000 cu. ft. of space; the maximum insecticidal effect with ethylene oxide was obtained in an atmosphere containing 30 pounds of carbon dioxide per 1,000 cu. ft.; and the maximum insecticidal effect with chloropicrin was obtained in an atmosphere containing about 37 pounds of carbon dioxide per 1,000 cu. ft.

Table 3 shows the effect of various concentrations of carbon dioxide combined with constant dosages of various standard fumigants. Adults of *Tribolium confusum* were used as test insects in all cases, the experiments being conducted in a 21.76-liter vacuum chamber at a constant

[1]F. L. Campbell, Chief of the Division of Insect Toxicology and Physiology of the U. S. Bureau of Entomology, has kindly made available to the writer an unpublished manuscript containing observations on the effect of mixing carbon dioxide with hydrocyanic-acid gas. The data corroborate the findings of the writer that the insecticidal effect of hydrocyanic-acid gas is not increased by the addition of carbon dioxide.

temperature of 86° F. The procedure consisted of placing 50 insects, in a cotton-stoppered glass vial, in the fumigation chamber, drawing a vacuum of 27 inches, then administering the carbon dioxide, after which the vacuum was broken with fumigant and air down to 5 inches.

TABLE 3. THE EFFECT OF VARYING CONCENTRATIONS OF CARBON DIOXIDE ON THE TOXICITY OF SEVERAL STANDARD FUMIGANTS

Carbon dioxide added per 1,000 cu. ft. *Pounds*	Kill of *Tribolium confusum* adults in 30 minutes at 86°F[1]. Chloropicrin 16.5 mg per liter *Per cent*	Ethylene oxide 24 mg per liter *Per cent*	Carbon disulphide 188 mg per liter[2] *Per cent*
0	10	18	48
5	22	25	85
10	33	28	92
15	50	59	97
20	57	61	—
25	68	74	—
30	78	93	—
35	91	94	—
36	94	—	—
37	97	—	—
40	96	93	—

[1]Average of 5 trials.
[2]1 hour exposure.

The carbon dioxide was drawn into the vacuum chamber directly from a cylinder of gas. At 86° F. 1 inch of vacuum corresponds to approximately 3.66 pounds of carbon dioxide per 1,000 cu. ft. of space with an atmosphere pressure of 760 mm.

In an empty fumigation chamber the toxicity of ethylene oxide against adults of *Tribolium confusum* is increased approximately four times by the addition of carbon dioxide and that of chloropicrin about two and one-half times. In an atmosphere containing 30 pounds of carbon dioxide per 1,000 cu. ft. of space a dosage of 24 mg of ethylene oxide per liter gave a 93 per cent kill of *Tribolium confusum* adults, whereas in the absence of the carbon dioxide a dosage of 96 mg of ethylene oxide per liter was required for a similar kill. Similarly in an atmosphere containing 37 pounds of carbon dioxide per 1,000 cu. ft. a dosage of 16.5 mg of chloropicrin per liter gave a 97 per cent kill of *Tribolium confusum* adults, and without the carbon dioxide a dosage of 41.25 mg of chloropicrin per liter was required to give a similar kill.

Apparently the increase in toxicity of carbon dioxide is not constant, but is influenced by the fumigant with which it is used. Probably the effect of the fumigants themselves on the insect tissues sometimes partially or wholly counteracts the action of the carbon dioxide. This is the case when hydrocyanic-acid gas is the fumigant. Hydrocyanic-acid gas inhibits the respiratory process by preventing the tissues from taking up oxygen.

In an attempt to determine whether or not the addition of carbon dioxide to a fumigation chamber would increase the toxicity of the fumigant used when the chamber was filled with material to be fumigated, the writer found (5) that the toxicity of the fumigant was increased whether or not the chamber was filled with material, and that if the chamber was filled with highly absorptive material a much greater toxicity was obtained with some fumigants than would normally be expected. This was illustrated in the fumigation by vacuum of raw peanuts. It was found impossible to obtain a 100 per cent kill of *Tribolium confusum* adults in 2 hours at 72° F. with chloropicrin alone, even when a dosage of 48 ounces per 100 cu. ft. of space was used. With the addition of 4.2 pounds of carbon dioxide per 100 cu. ft. a dosage of but 4 ounces of chloropicrin per 100 cu. ft. gave a 100 per cent kill.

THE COMBINED EFFECT OF INCREASING THE CARBON DIOXIDE CONTENT AND DECREASING THE OXYGEN CONTENT OF THE FUMIGATION CHAMBER. In considering the effects of carbon dioxide and of oxygen deficiency on the susceptibility of insects to fumigants, the question naturally arises whether or not a combination of the two factors would still further increase the insects' susceptibility.

In order to answer this question a series of tests were made with adults of *Tribolium confusum* in a vacuum tank of 21.76-liter capacity. A constant dosage of 16 mg per liter of ethylene oxide was used at a constant temperature of 86° F. and with a constant exposure of 30 minutes. One lot of 50 insects was fumigated in the ordinary way without the addition of carbon dioxide and without decreasing the oxygen content of the fumigation chamber; a second lot was fumigated in the presence of carbon dioxide at the rate of 30 pounds per 1,000 cu. ft. of space; a third lot was fumigated with the oxygen content of the tank reduced to approximately 0.7 per cent of an atmosphere; and a fourth lot was fumigated in the presence of carbon dioxide at the rate of 30 pounds per 1,000 cu. ft. and with the oxygen content reduced to approximately 0.7 per cent of an atmosphere. In the fourth test a 29-inch vacuum was drawn, the carbon dioxide added, then the fumigant, and the resulting vacuum held throughout the exposure. The insects in the fourth test consisted of two lots. One lot of 50 had, like those in the the first three tests, been kept at room temperature (about 75° F.) prior to fumigation; the other lot of 50 had been kept at a temperature of 50° F. for 3 days prior to fumigation. The results of these tests are given in Table 4.

TABLE 4. THE EFFECT OF VARIOUS FACTORS ALONE AND IN COMBINATION ON THE SUSCEPTIBILITY OF *Tribolium confusum* ADULTS TO ETHYLENE OXIDE

	Kill in 30 minutes at 86°F. with ethylene oxide at 16 mg per liter			
Temperature at which insects were kept prior to fumigation	Ordinary method of fumigation	With addition of 30 pounds CO_2 per 1,000 cu. ft.	With oxygen content of tank reduced to 0.7 per cent of an atmosphere	With addition of 30 pounds CO_2 per 1,000 cu. ft. and reduction of oxygen to 0.7% of an atmosphere
°F.	*Per cent*	*Per cent*	*Per cent*	*Per cent*
75	0	36	50	100
50	–	—	—	20

The data in Table 4 indicate that the two factors—an increase in the CO_2 content and a decrease in the oxygen content of the fumigation chamber—are more effective when used together than when either is used alone. If, however, the metabolic rates of the insects are decreased by holding them at a low temperature prior to the fumigation, the effects of the other two factors are almost nullified. The three factors are, therefore, most effective when used together. The toxicity of ethylene oxide to adults of *Tribolium confusum* is increased more than six times when these three factors are combined.

CONCLUSIONS. From the foregoing experiments it is evident that, other factors being normal, the susceptibility of an insect to a fumigant is influenced by any factor that affects the rate of metabolism of that insect. Any factor that increases the rate of metabolism increases the susceptibility of the insects to the action of a fumigant, and vice versa.

Of the known factors that increase the susceptibility of insects to fumigants, the three most important are: an increase in temperature; an increase in the carbon-dioxide content of the fumigation chamber; and a decrease in the oxygen content of the fumigation chamber. The most effective results are obtained through a combination of these factors.

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THE COTTONY CUSHION-SCALE IN PUERTO RICO

By M. D. LEONARD, formerly *Entomologist, Insular Experiment Station, Rio Piedras, P. R.*

ABSTRACT

A record of the discovery, spread and initiation of control measures of *Icerya purchasi* Mask. in Puerto Rico. Its food-plants are listed and natural enemies discussed, including the introduction and colonization of the Australian ladybeetle, *Rodolia* (*Vedalia*) *cardinalis* Muls.

DISCOVERY AND SPREAD. The middle of October, 1931, the writer learned that the cottony cushion-scale, *Icerya purchasi* Mask., had been found the preceding February by one of the Insular Plant Quarantine inspectors infesting a few rose bushes in his garden in Santurce, a suburb of San Juan. Specimens had already been sent to Washington thru the Federal Plant Quarantine Office, and the determination had been made by Dr. Morrison in April.

The latter part of October two specimens were brought by the Insular Forest Service to the Experiment Station for determination. They were on a shoot of Australian pine from an unknown place in Santurce. The Forest Service and the Federal and Insular Plant Quarantine Offices were at once notified to be on the lookout for this scale, especially on casuarina or Australian pine and on citrus. A check determination of this material was not received from Washington until the middle of February 1932. The writer was absent nearly the whole of the intervening time on official business in the States.

During March several casuarina trees and hedges were found lightly infested in San Juan and Santurce and at one place several gallego trees. Mr. C. E. Pemberton, Chief Entomologist of the Hawaiian Sugar Planters' Experiment Station, was with the writer at the time and took great interest in developments until he left the Island the middle of April. A meeting of the Insular Plant Quarantine Board was called on March 31 to consider plans for the future. The writer recommended further continued survey and the introduction of the Australian lady-beetle just as soon as an infestation should be found in sufficient concentration to support the beetles.

On April 2 a number of large bearing grapefruit trees in the Fletcher grove at Palo Seco, across the bay from San Juan, were found to be badly infested and many other trees in the grove lightly so. The adjoining Wildman grove was apparently only slightly infested, but subsequent more careful examination showed it to be widespread. The insects had just been noticed a couple of months before by Mr. Fletcher but had multiplied rapidly he said during the continued dry weather. Within the next two months three groves near Bayamón, and one grove in Dorado were found to be more or less infested. Since that time Dr. Wolcott reports (Bul. Insect Pest Surv. 12: 293) that two outbreaks, from 6 to 9 months old, have been discovered in Pueblo Viejo. Continued survey during April and into May disclosed that the casuarina trees and hedges as well as the ornamental citrus trees in many private homes all the way from San Juan south to at least Martin Peña, were infested. This included an area of about 5 miles long and a mile or so wide. Dorado is about 10 miles west of San Juan and Bayamón about 5 miles southwest; Pueblo Viejo is near Bayamón.

Food-Plants. As is well known, the cottony cushion-scale has a long list of food-plants thruout its range. Many of these occur in Puerto Rico and some of them are common there. The following are known to the writer as having actually been found infested up to July 1932: grapefruit, Australian pine (*Casuarina equisetifolia*), rose, gallego (*Polysias Guilfoylei*), gallito (*Agati grandiflora*), pigeon pea, *Acalypha* sp. and maría (*Callophyllum antillanum*). Its favorite host-plants so far on the Island apparently are citrus and casuarina but a number of maría trees in Santurce were considerably infested. Roses were attacked only in the original place of discovery and the remainder of the food-plants mentioned only found infested in a few instances. Pigeon peas are potentially an important host-plant since they are widely grown in Puerto Rico.

CONTROL BY SPRAYING. As soon as the first infestations were found on grapefruit, the writer recommended a special application of commercial oil-emulsion of the type now widely used on citrus; also pruning off and burning the most heavily infested branches. Special spraying and some pruning was also done at first in the infested groves in Bayamón and Dorado. After the initial shipment of Vedalia beetles arrived about 10 days later no further oil spraying was done on the more badly infested trees in the Fletcher grove in which most of the beetles had been released. The grove at Dorado was apparently sprayed heavily several times before Vedalias were introduced. Later on about 1500 trees which were considerably infested in the Wildman grove at Palo Seco were thoroly scrubbed with oil-emulsion. This was applied with stiff brushes down to even the smaller branches. Spraying followed each scrubbing. Two or three applications of oil-emulsion (about 2 gals. in 100 gals. water) were made to infested trees in the other groves. Most of the casuarinas and any other infested plants in the large San Juan-Martin Peña infestation were sprayed with oil applied with a fairly high power machine. Altho in many cases the spraying undoubtedly reduced the amount of scale present to a considerable extent, it proved on the whole, unsatisfactory, especially on citrus.

NATURAL ENEMIES. Upon the discovery of the first infested grove on April 2, 1932, the writer recommended the immediate introduction of the Australian ladybeetle. A conference was arranged for Monday morning, the 4th, with the Commissioner of Agriculture, and a cablegram was sent at once to the Florida State Plant Board requesting the beetles. A shipment of 15 colonies of 10 pupae each left Gainesville by air-mail the next day and arrived in San Juan the night of the 8th. On the 10th, in company with Mr. F. López Domínguez, Director of the Insular Experiment Station, and Dr. G. N. Wolcott, the Vedalias were released. The prompt assistance of Drs. Newell, Montgomery and Berger, of the Florida State Plant Board was greatly appreciated.

On April 21 a second air-mail shipment of 5 colonies of Vedalia material, also from Florida, was received in San Juan. This was released on the 23rd. Most of the beetles had already emerged and over half of them were dead. In company with Mr. Richard Faxon, chief of the local Federal Plant Quarantine Office, three boxes were placed in the Palo Seco groves and the remaining two in a clump of badly infested casuarinas near the new stadium outside of San Juan. Three beetles were saved for breeding purposes at the Insular Experiment

Station. Two colonies of Vedalias in the first shipment had been retained for breeding purposes but had died for want of proper care.

From the three above mentioned adults we were able to rear by a little after the middle of June about 450 adults in two generations. Of these about 400 were distributed between the middle of May and the middle of June to five of the six citrus groves infested up to that time. The rest were retained at the Station for breeding stock. A considerable number of beetles had been bred independently. It was found that the life-cycle was about 3 weeks from egg to adult, and that egg-laying started within 3 days after the emergence of the beetles. The breeding work was conducted by Mr. F. Sein, Jr.

By about the first of July the beetles had multiplied to such an extent that they had greatly reduced the infestation in the Fletcher grove and apparently were well established in the others. From an initial release of only 4 or 5 adults near the new stadium the considerable infestation on the casuarinas was reduced almost to nothing.

On April 1st it was noticed that many of the scales in the rose infestation were attacked by a dipterous maggot. The infested ovisacks contained 6 to 8 small puparia instead of eggs. The body of the scale insect itself was eaten out in most cases and all parasitized scales were dead. From then on almost every infestation examined was found to be more or less parasitized and often over 50% of the scales in a colony or on a tree would be killed as a result. The adults emerged in considerable numbers in our breeding jars. This fly has been since determined by both Messrs. C. T. Greene and J. R. Malloch as *Syneura coccidiphila* Coq. (Phoridae). It was described from three localities in Mexico as bred from larvae infesting dead adults of *Icerya purchasi* (See Coquillett in Can. Ent. 27: 106, 1895, as *Phora*). S. C. Bruner, of the Cuban Experiment Station (Inf. Dept. Ent. and Fitopath, for 1929–30, 1931) reports this Phorid as parasitizing the cottony cushion-scale in Cuba.

The next most important natural enemy in Puerto Rico is the lacewing fly, *Chrysopa collaris* Schneider. The trash-carrying larvae were usually found feeding in colonies of the scale, often commonly so, and a number of adults were reared. The pupal period occupied only 5 or 6 days.

The common ladybeetle, *Cycloneda sanguinea* L. was frequently found feeding both as adult and larva on the scales and the larvae of a moth, undoubtedly *Ereuntis minuscula* Wlsm. was several times observed making heavy inroads where the scales were thickly encrusting twigs or small branches. This latter species is not uncommon in the Island and

has been reported as feeding on several scale insects and as a scavenger in old cotton bolls and in the dry pods of okra and cowpeas.

PRESENT STATUS. According to Dr. Wolcott (l. c.) by some time in July the heaviest original infestation in Palo Seco was practically eliminated "in large part owing to spraying and the Australian ladybeetle, during dry weather, but the final clean-up is almost entirely due to a light gray fungus which has appeared in great abundance during the recent wet weather." The fungus, he says, also cleaned up a heavy infestation in Bayamón but in an adjoining grove neither beetles nor fungus prospered and the scale was more abundant than a month ago. He states that the beetles were known to be present in only one grove at that time and not in very great numbers. Wolcott further reports (Ins. Pest Surv. Bul., Sept. 1932) that a survey the middle of August showed the scale to be less abundant in citrus groves than at any time since its discovery.

Scientific Notes

Box Elder Bug on Strawberries. On August 18th, 1932, at St. Joseph, Michigan, an infestation of the Box Elder bug, *Leptocorus trivittatus* was observed on everbearing strawberries. Eggs, nymphs, and adults were extremely numerous. The nymphs were feeding on the foliage and fruit with the result that the entire crop was lost and great apparent damage inflicted upon the plants. Many plants were killed outright.

RAY HUTSON, *Michigan State College, E. Lansing, Michigan*

Hawaiian Parasite of Sugarcane Mealybug Sent to Louisiana. Some months ago Mr. O. H. Swezey, of the Hawaiian Sugar Planters' Association Experiment Station, kindly offered to make shipments to the Bureau of Entomology of (*Aphycus*) *Pseudococcobius terryi* Fullaway, a parasite of the gray sugarcane mealybug (*Pseudococcus boninsis* Kuwana) for release in Louisiana.

His offer having been accepted, four shipments of infested mealybugs were made to the U. S. Sugarcane Insect Laboratory at New Orleans. The mealybugs were sent in the cold rooms of ships to San Pedro, Calif., where they were received by Mr. A. P. Messenger, of the California Department of Agriculture, and immediately forwarded to New Orleans by air mail.

Every shipment arrived in good condition, and the parasite soon began emerging in numbers. It was found easy to breed, the only difficulty being the scarcity of the mealybugs early in the season when the shipments began to arrive.

Adults of this parasite were released at Cairo, Ga., in June. Other shipments have been released on two plantations in Louisiana a number of times previously.

The success of this work was due in large measure to the cooperation of Mr. Swezey and Mr. Messenger.

T. E. HOLLOWAY, *U. S. Bureau of Entomology, New Orleans, La.*

A Cage for Clothes Moth Larvae. A simple method of confining larvae of *Tineola biselliella* (Hummel) on small pieces of woolen cloth, while toxicity tests are being made either with fumigants or moth-proofing preparations, has been found very satisfactory during more than a year's use. Ordinary embroidery hoops, about 5 inches in diameter, are used as the foundation of the cage, and two pieces of muslin, cut slightly larger than the hoops, complete it. A piece of woolen cloth about 2½ inches in diameter is placed between the pieces of muslin, which are clamped together with the hoops. In order to avoid any possibility of crushing the larvae at the time the cage is closed, they should be placed just outside the edge of the woolen cloth and allowed time to establish themselves on the cloth before the test is begun. The cage will accommodate from 5 to 10 half-grown larvae. The number of larvae escaping from this cage has been found to be practically negligible, and it offers the added advantages of presenting a large surface of muslin for the passage of gas or for aeration, and of being quickly opened and closed for inspection of larvae. It is possible that this type of cage might be used for other insects, especially those which, like the clothes moth larva, prefer to be between two appressed surfaces.

WALLACE COLMAN, *Bureau of Entomology, U. S. Department of Agriculture*

The California Tortoise Shell Butterfly, *Aglais californica* (Bdv.), has been unusually abundant in California this summer and has been the cause of considerable damage to ceanothus bushes which are an important food for cattle in certain places. The area of infestation included the western foothills and slopes of the Sierra Nevada Mountains from Eldorado County on the south to Butte County on the north inclusively, and from the 2000 foot level to 7,500 in the vicinity of Lake Tahoe. Caterpillars were first noted in the foothill areas from Placerville to Berry Creek about the middle of May. On June 4, Lloyd W. Smith reported about 100 acres of deer brush, *Ceanothus integerrimus* H. & A., completely defoliated in Butte County. On June 8, I visited a portion of the infested area in Eldorado County and found that adults were emerging in countless numbers. They were moving out of the infested areas and seeking fresh plants at higher altitudes upon which to lay their eggs. In Eldorado County they were moving up the American River canyon and were to be found to the limits of the melting snow. On June 13 they had reached the 7,500 foot level and later on in the early part of July, I noticed them up to 7,500 feet where the caterpillars were feeding on snowbrush, *C. cordulatus* Kell. The adults of this second brood began to appear during the last of July and the first of August and were specially abundant in the Lake Tahoe region. In fact the gradual dispersal of the butterflies from the high altitudes to the lowlands caused considerable comment and the press ran a number of notices about this butterfly migration; the species having been both correctly and incorrectly determined.

This butterfly frequently occurs abundantly in middle and northern California and dispersal flights have been observed in many localities during past years.

E. O. ESSIG, *Berkeley, California*

An Experimental Corn Duster. In a series of experiments for the control of the Japanese beetle (*Popillia japonica* Newm.) on sweet and field corn, during the past season, various repellent dusts were used. The equipment generally used for

applying insecticidal and fungicidal dusts to orchard trees and nursery stock was experimented with, and, in addition, applications were made by hand. None of these methods was satisfactory, although it was noted that the corn nearest to the outlet of the various types of dusting machines used was protected much better than the rows farther away. With the cooperation of a commercial manufacturer of dusting equipment and after consultation with corn growers interested in the protection of sweet corn from beetle injury, the writer designed a four-row corn duster

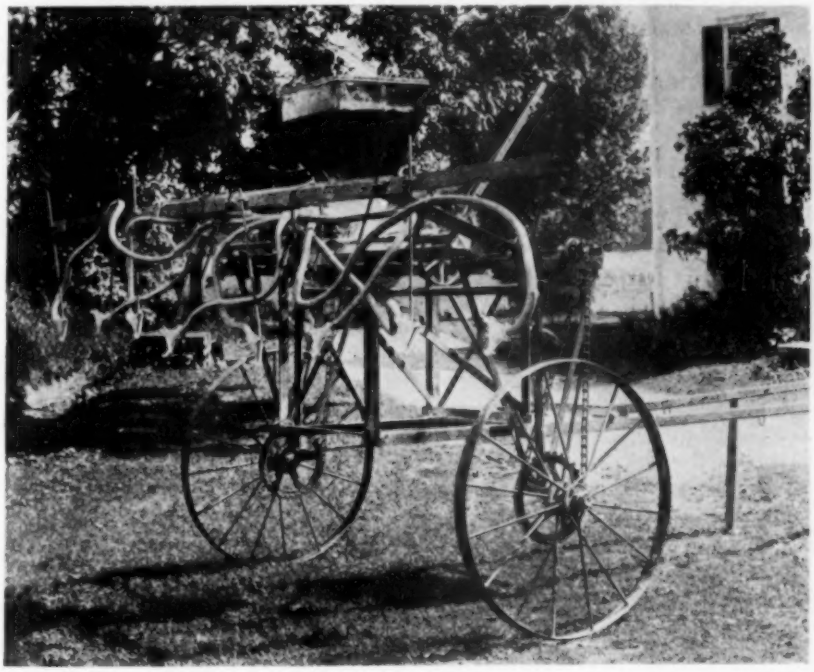

Fig. 78.—Rear view of experimental corn duster.

which gave very satisfactory results in a series of experiments conducted in 1931 at Southampton, Pa. The machine proved practical, efficient, and economical in distributing the repellent dusts on the corn plant; especially was this true in covering the silk, that portion of the plant which is most subject to attack by the beetle. With it, the work can be done many times faster than by any other known method.

An ordinary four-row crop duster is built up with a clearance of 5 feet by the use of a bent axle. The blower is traction driven, one horse being required to pull the machine. The horse, hopper, and blower pass down the center between the two middle rows and the two wheels between the center rows and the adjacent rows. There are eight outlets, two to a row, each fastened on a boom to the rear of the duster as shown in the accompanying illustration. The outlets are so arranged that each row or hill of corn is dusted from two sides. In our work 100 pounds

of dust was applied to an acre and three applications at intervals of three days were necessary to protect the corn. The machine is selling for approximately $225 at the present time.

E. R. VAN LEEUWEN, *U. S. Bureau of Entomology, Moorestown, N. J.*

The Natural Protection of Gladiolus Cormels from Thrips' Attack. In connection with the studies on control of *Taeniothrips gladioli* M. & S. on gladiolus corms in storage, observations on its habits and life history have also been made. The thrips breed during the winter on the stored corms. They feed directly on the surface of the corms, to which they gain access through cracks in the scales and between the leaves where the stalks were severed from the corms. It is noted that these insects seem unable to feed on the living tissue through even the thinnest scale. Thus one interesting fact, perhaps also of economic importance, brought out in this study, was the absence of thrips upon the true cormels or "bulblets." More than four thousand cormels of several varieties, stored in the same containers with heavily infested corms, were found to be entirely free of thrips or their injury. An examination of a cormel shows that it is completely encased in a thickened shell. Where the cormel is detached at its base from the connection with the parent corm the tissue of abscission is thickened and hardened, and completely fills the opening in the otherwise continuous capsule. The flesh of the cormel is inside beyond reach of the insects. A modified type of cormel, lacking the capsule-like covering, but possessing scales as do the much larger corms, occurs rarely but is readily distinguished from the usual type. This type is not protected from thrips' attack and so constitutes an exception to the present discussion.

The fact that the cormel being a completely sealed capsule, affords a natural protection from the thrips' attack is quite remarkable, since all other living gladiolus parts are naturally fed upon. In storage this includes the corm surface, young shoots, and rootlets; and, during the growing season, the foliage, flower stem, and all parts of the flower spike and flowers, including the developing seed pod.

A knowledge of this absence of thrips on cormels with unbroken coverings, even though taken from infested corms, may be of value both to the commercial grower and to the amateur.

FLOYD F. SMITH, *U. S. Bureau of Entomology, Washington, D. C.*

A Hitherto Unreported Curculionid Pest of Onion and Garlic in Texas. During February, 1932, while investigating cabbage-insect problems in the vicinity of Corpus Christi, Texas, complaints of insect damage to seedling onions were received. Upon examination the insect involved proved to be a weevil larva which was determined as a curculionid by Dr. A. G. Böving. Adults were reared from the larvae collected infesting onion and later referred to the Taxonomic Division of the Bureau of Entomology. They were determined as *Ceutorhynchus tau* Lec. by Mr. L. L. Buchanan. So far as can be ascertained, there is no published record of the habits of the species. The weevil was being referred to by the growers in the infested area as the "onion maggot."

Injury is confined largely to the terminal part of the sheathing bases of the leaves. However, an occasional larva was observed boring downward toward the crown and in the leaves. Infested plants were distinctly stunted and deformed, very often splitting and bending. The younger the plant is when attacked, the more severe

is the damage. It was reported that one 50-acre field of seedling onions in the vicinity of Robstown had been plowed under because of the damage caused by this pest. However, reports received later from the district were to the effect that infested crops recovered sufficiently to produce nearly normal yields.

According to information obtained by report and observation by Mr. G. D. Clark, Truck Crop Estimator of the U. S Department of Agriculture, and furnished the writer, onions and garlic were infested quite generally by the larva of this species on non-irrigated land from Raymondville, Cameron County, on the south to Schulenburg, Fayette County, on the north. Also Mr. Clark observed heavily infested garlic growing adjacent to seedling onions which were only slightly infested, thus indicating the insect's preference for the former.

CHARLES E. SMITH, *U. S. Bureau of Entomology*

Notes on a New Parasite of the Codling Moth. During the summer of 1929 a new Ichneumonid parasite of the codling moth was found to be quite common in some of the walnut orchards of Ventura County, Calif. R. A. Cushman[1] (1931) has recently described the insect as *Calliephialtes nucicola*. Most of the type material was sent from this station, but specimens are also listed by Cushman which were reared from an acorn of California White or Valley Oak (*Quercus lobata* Née), the gall of *Cynips maculipennis* (Gillette), and *Walshia amorphella* Clemens.

Between August 17 and September 20, 1929, from walnuts infested with codling moth in the laboratory 141 parasites were reared, 109 were males and 32 females. On August 23, 1929, a female was taken in an orchard ovipositing in a walnut infested with a codling moth. On August 29, 1930, a pupa of *C. nucicola* was found within the shell of a green walnut along with the remains of a codling moth larva. The pupa was protected by a frail white cocoon. On September 8, 1930, a male emerged. The earliest date that the parasite has been seen in the field was sixty days after codling moth larvae were first seen.

Frass or excreta of the codling moth furnishes the stimulus which brings about oviposition. The parasite will vainly attempt to oviposit in glass, wood or any other substance which has been in contact with frass.

Calliephialtes nucicola Cushman differs greatly in its life history from *C. messor* (Grav.) which was introduced into Calif. from Spain in 1904 by George Compere but does not seem to be established. (Smith and Vosler[2] 1914) *C. messor* (Grav.) oviposits on the hibernating larvae in the cocoon while *C. nucicola* Cushman will not attempt to oviposit on hibernating larvae unless frass is placed on the cocoon and the oviposition response brought about. Even then the parasite is unable to pierce the cocoon and the ovipositor often becomes entangled in the webbing of the cocoon causing the death of the parasite.

The manner in which *C. nucicola* maintains itself through the winter and early spring months when only hibernating codling moth larvae are present is not known. It is possible another insect serves as host during this period or it may hibernate as a larva or pupa within the shell of infested nuts or as an adult.

[1]Cushman, R. A. Descriptions of thirteen new American and Asiatic Ichneumon-Flies, with taxonomic notes. Proc. U. S. Nat. Mus., 79:1–16. 1931.

[2]Smith, Harry S. and Vosler, E. J. *Calliephialtes* in Calif. Monthly Bulletin, Calif. Com. Hort., 3:195–211. 1914.

The variation in size is great, females being from 5 to 15 mm. long, males from 3.5 to 9 mm. long.

R. E. BARRETT, *Entomologist Saticoy, Ventura Co. and Moorpark Walnut Growers' Associations*

Observations on the Association of Thrips with Arsenical Injury on Snap Beans. During the spring of 1932 at Norfolk, Va., there was a heavy infestation of the onion thrips (*Thrips tabaci* Lind.) on various truck crops, including snap beans. At this time a field control experiment was being conducted on snap beans for the control of the Mexican bean beetle (*Epilachna corrupta* Muls.) in which magnesium arsenate at the rate of 1 pound to 50 gallons of water was being used along with three non-arsenical materials. The first treatment was applied on May 20 and at this time thrips were observed on the plants in all plats. On May 26 the plats were examined and thrips injury was apparent on the lower leaves of practically all of the plants. The injury was in the form of a reddening of the leaves which closely resembled arsenical injury. The leaves on the plants in the magnesium arsenate plat showed thrips injury similar to that on the other plats but in addition leaf burn which was not observed on the other plats was noticeable. At the time of the second treatment (May 31) thrips were still numerous and it was decided to apply 40 per cent nicotine sulphate at the rate of 1 to 400 with each material being used. On June 3 the plats were examined and it was apparent that the magnesium arsenate plat was considerably injured by the arsenical but no additional injury following the second treatment was seen. There was noticeable leaf burn and shedding of the leaves on this plat which was not observed on the plats treated with the non-arsenical materials. A close examination showed that the nicotine sulphate (1 to 400) applied with the regular materials had given good thrips control. The third treatment was applied on June 7. Nicotine sulphate (1 to 400) was again applied with each material. On June 21 the plats were examined and it was found that the magnesium arsenate plat had recovered to some extent from the insecticide injury and no additional injury was observed. The entire rows in this plat appeared narrow and dwarfed owing to the leaf burn and shed previously noted. The fact that no additional insecticide injury was noticeable on the magnesium arsenate plat after the thrips were controlled by the addition of nicotine sulphate indicated that there was a relationship between the thrips infestation and the arsenical injury. Yield records were obtained and there was a slight reduction in yield on the magnesium arsenate plat as compared with check plats.

These observations were confirmed by applying four treatments of the following materials to snap beans in another location where thrips were numerous: Magnesium arsenate (obtained in 1931) 1 pound to 50 gallons of water; magnesium arsenate (obtained in 1932) 1 pound to 50 gallons of water; 1932 magnesium arsenate 1 pound to 50 gallons of water with 40 per cent nicotine sulphate 1 to 400; 1932 magnesium arsenate 1 pound to 50 gallons of water with nicotine sulphate 1 to 800. The magnesium arsenate purchased in 1931 was used in this experiment with the 1932 material so as to eliminate the possibility of the magnesium arsenate being a factor in the damage. The beans used in this experiment were blooming and setting small pods at the time of the first treatment and thrips injury was apparent on the leaves of the majority of the plants. The results checked with the

previous experiment in detail. Insecticide injury on the plats treated with 1931 and 1932 magnesium arsenate was estimated at 30 to 35 per cent leaf burn and shed. On the plats treated with magnesium arsenate and nicotine sulphate (1 to 400 and 1 to 800) no insecticide injury was observed. At the conclusion of the experiment thrips injury on the plats treated with magnesium arsenate and nicotine sulphate was rated at 5 per cent while that on adjacent check plats was rated at 35 to 45 per cent.

In a later experiment, conducted during July where no thrips were present, four applications of 1932 magnesium arsenate resulted in no insecticide injury.

Thrips have rasping-sucking mouth parts which tend to lacerate the epidermis of a leaf before the exuding sap is sucked. It is possible that the arsenical gained entrance into the leaf tissue at the time of feeding, thus causing insecticide injury in association with thrips which was not apparent on beans where the thrips were controlled by nicotine sulphate in combination with the arsenical.

It would appear from these preliminary observations that when treating beans which have thrips infestation in addition to a Mexican bean beetle infestation, nicotine sulphate should be applied with the magnesium arsenate in order to control the thrips and to avoid the possibility of insecticide injury from the arsenical.

L. W. BRANNON, *Assistant Entomologist, U. S. Bureau of Entomology*

THE ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The ninth Rocky Mountain Conference of Entomologists was held at the Colorado Agricultural College Forestry Lodge, Pingree Park, Colorado, August 15 to 20, 1932, inclusive. A total of 88 registered during the week, 46 of these, representing 11 states and 16 educational institutions or entomological organizations, were directly interested in entomology. The remainder were members of families or friends. Ideal weather for collecting and an outing made the occasion a very pleasant and profitable one. The following is a list of those directly interested in entomology:

F. B. Paddock, Bernard Travis, C. H. Richardson, Ames, Iowa; Geo. A. Dean, J. E. Ackert, Donald A. Wilbur, C. R. Collins, Manhattan, Kansas; Katherine C. Doering, Paul B. Lawson, Lawrence, Kansas; Claude Wakeland, Moscow, Idaho; Leonard Haseman, Columbia, Mo.; Alexander B. Klots, Elsie B. Klots, Rochester, N. Y.; Otis Wade, Eugene F. Powell, L. M. Gates, Lincoln, Nebraska; A. W. Lindquist, Uvalde, Texas; C. L. Fluke, Madison, Wisconsin, C. L. Hayward, Vasco M. Tanner, Provo, Utah; Lee Jeppson, Brigham City, Utah; John W. Scott, Laramie, Wyoming; L. G. Davis, Grand Junction, Colo.; J. H. Newton, Chas. M. Drage, Paonia, Colo.; Harold E. Rice, E. R. Bliss, Greeley, Colo.; F. Martin Brown, Colorado Springs, Colo; Orville Hitchcock, Montrose, Colo.; Maurice T. James, Boulder, Colorado; M. A. Palmer, L. B. Daniels, John Weaver, S. C. McCampbell, C. A. Bjurman, R. G. Richmond, G. M. List, Lee Jenkins, Leonard Sweetman, C. P. Gillette, F. T. Cowan, J. L. Hoerner, Jack Manweiler, S. Arthur Johnson, C. R. Jones, Fort Collins, Colo.

More than the usual number of systematists were present, which resulted in a large number of insects being taken from the varying conditions represented by the lakes, meadows and mountain areas that range from 9000 feet altitude to above timberline and snow. A total of 10 sessions were held during the week for discussion and presentation of papers. The following is a list of the more formal subjects discussed:

Life History of the Hour Glass Spider.—P. B. Lawson
Pasture Insect Investigations.—Donald A. Wilbur
White Grubs.—C. L. Fluke
White Grubs in Iowa.—Bernard Travis
University Life in England and Civic Life on the Continent—Illustrated.—J. E. Ackert.
Cercopidae.—Katherine C. Doering
Remarks on Insecticide Research.—C. H. Richardson
Entomological Supplies.—Alexander B. Klots
Sub-Specific Nomenclature of Insects.—Alexander B. Klots
Symposium—Entomological Collections of the Rocky Mountain Region. Leaders—Vasco M. Tanner, F. Martin Brown, and C. L. Fluke
The Role of Insects in the Food of Trout in the Rocky Mountain Region.—John W. Scott
Codling Moth Control in Missouri.—Leonard Haseman
Grasshopper Bait Tests in Colorado.—F. T. Cowan
Notes on the Stratiomyiidae in Colorado.—Maurice T. James
Stretchia plusiiformis Hy. Edwards, a Pest on Gooseberries.—J. L. Hoerner
The Cabbage Looper on Lettuce—S. C. McCampbell
Paper Wasps of Utah.—C. L. Hayward
The Preparation of Granulated Honey for the Market.—R. G. Richmond
Taxonomic Aspects of Aphids on Ribes.—Miriam A. Palmer
The Potato Psyllid.—L. B. Daniels
Faunal Survey of Colorado.—F. Martin Brown
The Romance of the Honeybee.—F. B. Paddock
Mineola scitulla Hulst., an Enemy of Stone Fruit in Idaho.—Claude Wakeland

The symposium on the subject of entomological collections for the Rocky Mountain region resulted in the appointment of a committee consisting of F. Martin Brown, Vasco M. Tanner and Geo. M. List, Chairman, to endeavor to encourage workers that collect in the Rocky Mountain region to return to museums within the Rocky Mountain area, as many specimens as possible that accurately determined material may be available for students of this region. It was felt that there is a very definite need for this and that many workers will be glad to have their material available for such use.

Officers elected for 1933 were C. P. Gillette, Chairman; Geo. A. Dean, Vice-chairman; Geo. M. List, Secretary and C. R. Jones, Treasurer.

A more complete report will be mimeographed and sent to those that have attended the various conferences and others that may request it.

GEORGE M. LIST, *Secretary*

JOURNAL OF ECONOMIC ENTOMOLOGY

OFFICIAL ORGAN AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

OCTOBER, 1932

The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication at $3.00 per page. There is a charge of $3.00 per page for all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptance illustrations. Photo-engravings may be obtained by authors at cost.

Separates or reprints, if ordered, when the manuscript is forwarded, will be supplied to authors at the rates given below. Note that the number of pages in a reprint may be affected somewhat by the make-up, and that part of a page is charged as a full page. Carriage charges extra in all cases. Shipment by parcel post, express or freight as directed.

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A. A. A. S. Winter meetings: 1932-33 Atlantic City; 1933-34 Boston; 1934-35 Pittsburgh; Summer meetings: 1932 Syracuse, 1933 Chicago, 1934 San Francisco.

The recent discovery of a large infested area near Pittston, Pa., brings the gipsy moth problem to the front. This is particularly true, since this new infestation necessitates the withdrawal of funds really needed for the adequate maintenance of the very important Barrier Zone. This latter is a project of National importance, since it protects many states not infested by the gipsy moth. It is obvious that there is little use in limiting the spread of the pest if it is allowed to breed freely in remote sections of the supposedly protected area. It is a fundamental principle of military strategy not to allow the enemy to entrench himself behind the line of defense. This is equally true in economic entomology. Nine years' experience with the Barrier Zone has abundantly demonstrated its value. It has prevented the westward spread of the insect, and judging from the history of the pest in New England, it has proved far more economical as a control measure than if the insect had been allowed to spread and repressive measures necessarily extended to much larger areas than at present. The State of Massachusetts all but attained extermination of this pest by 1900. The very excellence of the work brought about its condemnation because many failed to appreciate the potentialities of this dangerous pest. Some twenty-eight million dollars have been expended upon this insect and a failure to continue present control operations must inevitably result in greatly increased injury. There must be either adequate maintenance of the Barrier Zone and the correlated elimination of outlying infestations or a material change in our policy in regard to this insect. The gipsy moth work is one of the out-

standing examples of successful large scale control. The peculiar physical limitations of the moth are important factors. They make possible a much more rigid restriction of spread than can be obtained with most insects. The gipsy moth is a serious pest of woodlands and a very destructive shade tree insect. Inadequate funds for the maintenance of the Barrier Zone and the eradication of outlying infestations mean the wrecking of an undertaking which can be abundantly justified from both economic and scientific considerations.

Reviews

Laboratory and Field Manual of Economic Entomology by JOHN R. EYER, 132 pages, Edwards Brothers, Inc., Ann Arbor, Mich., 1932.

The title of this work indicates the general field covered. The first part is concerned with insect anatomy and physiology, development and metamorphosis and the classification of insects. The second part deals with control measures by chemicals, by mechanical and cultural methods, by legislation or quarantine and through biological control. The third part is concerned with the literature of economic entomology and the preparation of an entomological thesis, really training for the working up and presentation of results. The fourth part deals with collecting and rearing of insects, instructions for field trips, mounting and preserving insects. This is followed by a very serviceable key to the more common insects designed to assist the student in recognizing pests under field conditions.

The work is comprehensive and should prove a valuable guide to the beginner. It does not tell the student too much and on the other hand provides a very satisfactory guide or approach to various problems confronting the student of insect life. It is a very successful example of lithoprinting, and since this is upon only one side of the paper there is an opportunity for supplementary notes throughout the volume.

E. P. FELT

Insects and Diseases of Ornamental Trees and Shrubs by E. P. FELT and W. H. RANKIN. 507 pages, profusely illustrated. Rural Science Series, The Macmillan Co., New York City, 1932.

This book is quite evidently written to fill an important and long felt need, namely, for a semipopular reference work on the commonest diseases and insects of ornamental trees and shrubs. It is designed particularly for the tree owner, the commercial tree man, and others who have not specialized in either entomology or pathology, but who have a very real interest in tree and shrub difficulties or a need to know about them. It has a broad scope and is written in simple and easily understood language. The first part is composed of chapters dealing with insects, fungi, insecticides, and fungicides, and injuries other than those caused by organisms. The second part contains, under an alphabetic arrangement of the host trees and shrubs, brief accounts of the important insects and diseases of each plant, with recommendations for control. This method of handling the various trees and

shrubs alphabetically is especially suited to a book like the present one, since it is thus easy to find the prominent pests of any particular plant.

In the selection of the subjects for discussion, emphasis has been laid upon the insect and disease problems of the northern and eastern parts of the United States, and there is a lack of information on the distribution of certain pests that is a disadvantage. This is especially true where the organisms involved are definitely limited in area.

Drs. Felt and Rankin have reduced somewhat the content of technical material in the book in order to favor the layman, but the writer would suggest the inclusion of something in the nature of a key which would enable readers to run their problem through a table of symptoms and other diagnostic factors and thus arrive at the name of a specific tree trouble and a page reference.

WILLIAM MIDDLETON, *Entomologist*

Iconographia Insectorum Japonicorum (Nippon Konchu Zukan), Hokuryukan, Tokyo, 1932. Price 15 Yen. Orders may be placed through Professor Teiso Esaki, College of Agriculture, Kiushiu Imperial University, Fukuoka, Japan.

The present work is a well-bound portly octavo of more than 2400 pages, illustrating more than 4000 species of insects inhabiting Japan and Formosa. The monograph was prepared by 26 of the leading specialists in Japan. The plan of the work is to illustrate two species of insects on each page, with a detailed discussion of the species in question immediately beneath the figure. The text is in Japanese but the remarkably accurate figures, each with its scientific name, render the work usable to all scientists.

The work begins with a 97-page, 2-column, scientific index, followed by a 123-page Japanese index. Then follows a table of all orders of insects giving the most recent views of Imms, Comstock, Handlirsch and Crampton. The main body of text is taken by the following groups of illustrations, the figures given indicating the number of species treated: A series showing the chief types of larvae and nymphs, 218; Apterygota, 28; Orthoptera, 156; Dermoptera, 20; Plecoptera, 26; Isoptera, 12; Embiidina, 24; Corrodentia, 20; Mallophaga-Anoplura, 54; Ephemerida, 24; Odonata, 104; Thysanoptera, 16; Homoptera, 368, including 70 Coccidae; Heteroptera, 284; Neuroptera, 62; Mecoptera, 16; Trichoptera, 28; Lepidoptera, Heterocera, 918; Rhopalocera, 398; Coleoptera, 700; Strepsiptera, 3; Hymenoptera, 450; Diptera, 473, including 50 Culicidae; Siphonaptera, 10.

The work is concluded by 24 remarkably beautiful colored plates, two each being devoted to the eggs, larvae and pupae; one to a comparison of lotic and lenitic water insect life; the remainder showing characteristic species in the various orders.

The volume will be found to be of great value to a variety of entomological needs.—(1) Those persons interested in geographical distribution who require a true picture of the fauna of Eastern Asia, somewhat comparable to that earlier presented by Tillyard's "Insects of Australia and New Zealand"; (2) The economic entomologist and all those interested in foreign quarantines will find here a wealth of material on species that may some day become introduced into America; (3) The specialist in any group of insects will find here unusually accurate figures

presenting only a slightly abridged account of his particular group. The reviewer can vouch for the uncanny accuracy shown by the 74 figures of Tipulidae in the work.

The present favorable balance of exchange will enable American students of insects to secure a copy of this fine work at the present time at a cost of approximately five dollars. C. P. ALEXANDER

Current Notes

Herbert L. Dozier was engaged in special investigations May to July inclusive for the Illinois State Natural History Survey.

At the request of the Superintendent of Algonquin Park, Mr. C. R. Twinn, Entomological Branch, visited the Park Headquarters at Cache Lake, in mid-May, to organize a mosquito control project. While there he also carried out some preliminary experiments on the effect of miscible oils on blackfly larvae in streams.

Mr. Arthur Gibson, Dominion Entomologist, sailed from Montreal for Europe, on July 1, on board the S. S. Aurania. Mr. Gibson's trip was primarily in connection with the Fifth International Congress of Entomology being held in Paris, July 16–23. Both Mr. Gibson and Mr. L. S. McLaine represented Canada at the Congress.

Dr. M. D. Leonard, for the past two and a half years Chief, Division of Entomology, Insular Experiment Station, Rio Piedras, Puerto Rico, has resigned his position there effective September 15. His address until further notice will be care Department of Entomology, Cornell University, Ithaca, New York.

The grasshopper outbreak in Manitoba this season is the most severe experienced for many years and despite a splendid control organization, it is feared that much crop damage will occur. Mr. Norman Criddle is assisted in this work by Messrs. R. H. Handford, R. H. Painter and P. C. Brown, the latter of the Division of Foreign Pests Suppression.

The Cambridge Entomological Club, at its 506th meeting, elected the following officers for the current year: Pres., C. W. Collins, U. S. Bureau of Entomology; Vice-Pres., C. W. Johnson, Boston Society of Natural History; Secretary, J. W. Johnston, Graduate Student of Harvard; Treasurer, Fred Walker of Salem, Mass. Prof. C. T. Brues of Harvard was continued as Editor of Psyche. Mr. Johnson died on July 19.

Craig W. Eagleson, formerly of Iowa State College, Ames, Iowa, was granted the degree of Doctor of Philosophy at the August convocation at Ohio State University. Mr. Eagleson has been appointed as exchange fellow by the Institute of International Education and will spend the coming year studying under the direction of Dr. Karl von Frisch at the University of Münich, Germany. He has been studying various phases of insect respiration.

In the early part of June, Mr. Gibson, Dominion Entomologist, spent a week in southern Ontario visiting Branch laboratories and Plant Inspection Stations to view the progress of the season's investigations. He also supervised arrangements for the establishment of a temporary laboratory in the Ridgeway district for a study

of the pine shoot moth which is becoming a serious pest. Mr. J. J. deGryse of the Division of Forest Insects is taking charge of this work.

Mr. G. Wishart, Entomological Branch, of the Belleville Parasite Laboratory, is rearing the following species parasitic on the European corn borer for liberation in infested areas: *Microbracon brevicornis, Exeristes roborator, Microgaster tibialis, Chelonus annulipes,* and *Inareolata punctoria.* He is also rearing *Trichogramma minutum* from eggs of *Sitotroga cerealella* for liberation against the oriental fruit moth. Mr. W. E. Steenburgh is rearing for liberation, *Ancylis comptana, Macrocentrus ancylivora* and *Calliephialtis grapholithae,* all parasites of the oriental fruit moth. Mr. A. R. Graham is engaged in recovering *Mesoleius tenthredinis,* a parasite of the larch sawfly, for liberation elsewhere, and in studying the larch case bearer and pine shoot moth.

Dr. J. M. Swaine and Mr. R. E. Balch, Entomological Branch, attended a conference of provincial foresters held in Quebec City on May 17, in connection with the white spruce sawfly outbreak in the Gaspe Peninsula. Pulp and lumber companies with holdings in the Gaspe, and the Quebec Forest Industries Ltd., were represented as well as the Quebec Forest Service. After a thorough discussion of the situation, arrangements were made for a co-operative investigation of the outbreak. Accordingly, a study camp was established at Kelly's Camp on the headwaters of the Grand Cascapedia in the Gaspe, early in June. Mr. Eric Watson who left Ottawa for Grand Cascapedia early in May, has charge of an investigation of the eastern spruce bark beetle which is causing extensive mortality in sawfly-infested spruce. He is assisted in this work by Mr. L. LaRue.

On May 11, scouting for the European pine shoot moth was started in the Toronto district of Canada. This work also has been conducted in the Windsor and Niagara Falls districts, Ont., in the Montreal district, Que., at Halifax, N. S., Saint John, N. B., Quebec, P. Q., Ottawa, Ont., Winnipeg, Man., and Estevan, Sask. In the Montreal, Toronto and Niagara Falls districts, where it has been found, a special attempt in eradication, by the pruning method, has been conducted and, although late in starting, due to the lack of staff, marked progress has been made. The most serious outbreak is along the shore of Lake Erie in Welland county. It is important to prevent the spread of this pest, and to this end the Ontario Department of Forestry, is cooperating with the Entomological Branch by supplying men and cars. Owing to the life-history of the insect, it was necessary to discontinue the work at the end of June. Mr. McLaine visited western Ontario, June 6 and 7, to make arrangements for the above eradication campaign.

Horticultural Notes

The State Entomologist of Virginia reports that nematode infestation in narcissus bulb plantings have been found more general this year than heretofore.

The Michigan State Department of Agriculture has issued a quarantine restricting the shipment of potatoes from California, Florida, Texas, and Virginia, on account of the potato tuber moth.

The Arkansas State Plant Board has modified the specifications governing the certification of sweet potatoes, adding a new grade called "certified vine cutting seed." The previous classes have been "Grade A" and "Grade B."

The State Entomologist of West Virginia reports as the principal news item from that State the fact that the State has not placed any quarantine concerning the European corn borer since the Federal quarantine on this insect was revoked.

Mr. Lee A. Strong, Chief of the Bureau of Plant Quarantine, spent part of August and September on a trip to the Pacific Coast for the purpose of consulting with Bureau employees and collaborators on plant quarantine problems.

Japanese beetle flight period for the summer of 1932 was reported to be over by September 17 and the Secretary of Agriculture on that date removed the farm products restrictions of the Japanese beetle quarantine regulations for the remainder of the season. The restrictions on cut flowers were continued until October 15.

Dr. S. B. Fracker of the Bureau of Plant Quarantine late in August consulted with the plant quarantine officers of a number of the New England States with respect to the protection of nurseries against the white pine blister rust and to proposed modifications of the Federal white pine blister rust quarantine regulations.

The Commissioner of Agriculture of Idaho has issued a quarantine restricting the shipment into that State of black locust plants and black locust products to prevent the introduction of the locust borer (*Cyllene robiniae*). The infested territory is designated as "practically all of the United States east of the eastern border of Arizona, Utah, Idaho and Montana."

The State Plant Board of Florida modified Rule 30, relating to the brown rot of lemons and oranges, effective August 16, 1932, to provide for the movement of citrus fruit from California when prepared in accordance with the instructions of the State Plant Board and certified to that effect, subject to detention and inspection for brown rot on arrival in Florida.

The California State Department of Agriculture on July 11 revised Quarantine Regulation No. 1 pertaining to the walnut husk fly, to extend the territory under quarantine in San Bernardino County and also to place an additional small section of Los Angeles County in the vicinity of Glendora in the quarantined territory. Additional changes made provision for the movement under certification and permit of walnuts from the regulated area to packing houses outside thereof.

On June 15 the Arkansas State Plant Board adopted a new rule under which shipments of apple seedlings originating in Kansas must bear on each package or container a special certificate signed by the Kansas State Entomologist, stating that all the apple seedlings grown by the shipper were inspected after September 1 and that not to exceed five per cent of the seedlings were affected with blotch canker.

Mr. Wendell P. Brown has succeeded Mr. George E. Harter as Supervisor of Horticulture of Washington. Mr. Brown was previously Horticultural Inspector-at-Large at Yakima, Washington. Mr. Harter was transferred to Wenatchee, Washington, where he will continue as Horticultural Inspector-at-Large, the work in which he was engaged before his transfer to Olympia. Mr. A. C. Rich succeeded Mr. Brown as Horticultural Inspector-at-Large at Yakima, Wash.

According to information supplied by the Georgia State Entomologist to the Bureau of Plant Quarantine, the Georgia quarantine relating to the sweet potato

weevil was modified in June, 1932, removing from the territory designated as infested, Baldwin County, Ala., the City of Birmingham, Ala., and the entire State of Oklahoma. The State Entomologist also reported the cancellation of the quarantines formerly issued with respect to citrus canker, spiny citrus white fly, and other citrus pests, and sugarcane mosaic disease.

The alfalfa weevil quarantine of California was revised effective August 20, eliminating Sioux County, Nebraska, from the quarantined area; extending the sections of California into which hay might be moved from Nevada under permit; removing the restrictions on the movement of nursery stock from quarantined areas; authorizing the shipment of alfalfa meal into California in bulk as well as in sacks, and eliminating the affidavit and permit requirements with respect to household goods and farm machinery respectively.

The Mexican fruit worm quarantine regulations restricting the shipment of fruits from Cameron, Hidalgo and Willacy Counties, Texas, were revised effective September 1 to make provision for the sterilization of citrus fruit whenever conditions necessitate such a requirement, to authorize the limitation of permits as to destination, to include a requirement that lot shipments of six or more containers by freight or road vehicles must be accompanied by master permits, and to make other changes in the requirements enforced to prevent the spread of the Mexican fruit worm from that area.

The discovery of an outbreak of the gipsy moth in northeastern Pennsylvania near Pittston in Luzerne County was announced by the Bureau of Plant Quarantine of the United States Department of Agriculture, in August. The infested area consisted principally of cut-over land, the main body of the infestation being within an area about eight miles long and four miles wide. Its extent indicates that the gipsy moth has been present in the region for a period of approximately fifteen years. Eradication measures were immediately undertaken by the Federal Department of Agriculture and the Pennsylvania Department of Agriculture working in cooperation.

The host-free period under the Mexican fruit worm quarantine regulations applying to the Lower Rio Grande Valley of Texas was terminated for the year 1932 by Lee A. Strong, Chief of the Bureau of Plant Quarantine, on September 15. Under this order citrus growers were authorized to begin fruit shipments so far as the Federal quarantine regulations were concerned, on the date given. Mr. Strong stated that no specimens of the fruit worm were taken in Texas during the summer after the middle of June and that the growers vigorously carried out the needed suppression measures, including the application of a bait spray and the destruction of all susceptible ripening fruits.

The Federal quarantine relating to the prevention of spread of the white pine blister rust within the United States has been revised effective January 1, 1933, to add Iowa, Maryland, Ohio, Virginia, West Virginia, and the District of Columbia, to the list of infected States. The embargoes which previously prohibited the shipment of five-leafed pine from the eastern United States to the West and from infected to noninfected States were removed, and the shipment throughout the United States of pines which had been protected against blister rust by means of Ribes

eradication was authorized under Federal permit. Under the new regulations, currant and gooseberry plants will hereafter not be required to be disinfected in lime-sulphur solution unless shipped with leaves or active buds.

Subsequent to the revocation of the Federal European corn borer quarantine, the following States issued plant quarantine orders and proclamations in order to prevent the introduction of the European corn borer within their borders: California, Florida, Georgia, Illinois, Iowa, Kansas, Louisiana, Missouri, Nebraska, Nevada, Oklahoma, Texas, and Wisconsin. These State orders, in every instance, covered the infested States in their entirety rather than only the known infested portions. The quarantines of California, Georgia, Nevada and Louisiana were issued as complete embargoes against the shipment of susceptible products, while in the other cases, certification by the State nursery inspection officers of the State of origin that the shipments concerned were free from infestation with the European corn borer, was authorized as a condition for the admission of the products concerned.

The requirement that cotton produced and ginned in the Salt River Valley of Arizona and certain adjoining sections of that State and New Mexico be fumigated as a condition of interstate movement under the pink bollworm quarantine regulations was removed by the Bureau of Plant Quarantine, effective September 15. The suppressive measures taken in that area included a noncotton zone during the year 1930, and limitations on planting date and other pest suppressive measures during the years 1931 and 1932. The scattered infestation found in 1929 and 1930 was so rapidly reduced that only two limited spots of infestation were found in the 1931 crop and careful inspections made during the summer of 1932 had not shown any indication of infestation in that region up to the middle of September. The effect of the order is that fumigation of cotton grown in the United States is being required this season only as to cotton produced in Terrell, Presidio, Brewster, Jeff Davis, and Culberson Counties and parts of Hudspeth County, Texas, and in those parts of southeastern Arizona regulated on account of the Thurberia weevil; namely, Cochise and Santa Cruz Counties and parts of Pima, Pinal, and Graham Counties.

Secretary of Agriculture Arthur M. Hyde held a public hearing October 4 to consider the advisability of extending the Japanese beetle quarantine to the States of Maine, Michigan, New Hampshire, North Carolina, Ohio, South Carolina, Vermont, and West Virginia, and to the unquarantined parts of Maryland, Massachusetts, New York, Pennsylvania, and Virginia. In connection with the announcement, the Department reported the finding of Japanese beetles this year at Augusta and Portland, Me.; Detroit, Mich.; Concord, Dover, Keene, Manchester, Portsmouth, and West Lebanon, N. H.; Durham, Raleigh, and Winston-Salem, N. C.; Canton, Cleveland, Columbus, Steubenville, and Zanesville, Ohio; Florence, S. C.; Bellows Falls, Brattleboro, and White River Junction, Vt.; and Charles Town, Martinsburg, and Wheeling, W. Va. Japanese beetles had not previously been captured at any of these locations except Columbus, and Cleveland, Ohio, where a number were taken in 1931. Additional infestations found this summer outside the regulated areas in the States already under quarantine included 21 localities in Maryland, 27 in Massachusetts, 20 in New York, 27 in Pennsylvania, and 17 in Virginia.